The Integrated Learning Initiative
An Evolution of a Pedagogical Paradigm

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Abstract

Queen's University, Kingston, Ontario has embarked on a new approach to engineering education in the faculty of Applied Science, known as the Integrated Learning Initiative. This new approach is to a large extent a result of two successful undergraduate programs. One course APSC100 is a first year engineering initiative, which introduces students directly into design and analysis exercises. APSC400, (Technology Engineering and Management, TEAM) is a fourth year engineering program. The Integrated Learning Initiative will extend the concepts developed in these two programs at opposite ends of an engineering student's undergraduate career, to cover much of the intervening period, and accommodate more students in the first and fourth years.

Queen's has traditionally had a common first year for engineering students. Some of the first year laboratories seemed to do more to dissuade students from pursuing an engineering career than to encourage them. Recognizing that students come to Queen's to be engineers; the first year program was redesigned over a period of three years, starting with a pilot program known as QUYFAS, Queens University First Year Applied Science. This program provided the students with the opportunity to engage in group problem solving/design exercises. The results have been most encouraging and now all first year engineering students participate.

TEAM was an initiative that was first offered in 1994/5. The Department of Chemical Engineering and the School of Business jointly developed what was initially known as TIP, Technology Innovation Program, which is now known as TEAM Technology Engineering and Management. TEAM places multidisciplinary teams of students as consultants for an eclectic array of industries. These teams must negotiate contracts, waivers of liability, confidentiality agreements, and IP agreements with their clients.

The TEAM program has evolved over the years that it has been in operation. This has been a significant learning experience for not only the participants, but also the coordinators and our industrial clients. It has certainly been a success, having received the prestigious Medal for Distinction in Engineering Education (1998) from the Canadian Council of Professional Engineers.

The Faculty of Applied Science has embarked on an Integrated Learning Initiative built upon the success of these two programs. While it is clearly recognized that this active learning style may not be appropriate for all course work, it certainly is the medium of choice for much of engineering education. A significant part of the Integrated Learning Initiative will be the

construction of an Integrated Learning Center, however a significant overhaul of the overall engineering curriculum will be a necessary companion to this phase of this endeavour.

History of Queen's University and Faculty of Applied Science

http://appsci.queensu.ca/about/history.htm

Queen's University was established by Royal Charter of Queen Victoria in 1841. The earliest degree-granting institution in the united Province of Canada, Queen's has helped to shape the values of Canada, educating many of its most notable political figures and public servants.

Queen's is well known as a university where an emphasis on teaching combines with top-flight research to create distinguished undergraduate curriculum. Queen's students come from every province and territory of Canada and from more than 70 nations around the world. An undergraduate enrolment of approximately 11,000 students keeps the university small enough to preserve a strong sense of community and manageable class sizes, yet large enough to allow a variety of course offerings.

Since its inception in 1893, Queen's Faculty of Applied Science has graduated more than 21,000 engineers, many of whom have distinguished themselves nationally and internationally. The faculty provides instruction to more than 2,100 undergraduate students each year in 10 engineering disciplines.

Over the ensuing years, there have been many changes, particularly in the Faculty of Applied Science. In recent years the Faculty has had to reflect on the path forward for the various programs in the faculty. It was realized that Queen's has some major strengths that we could build upon, such as a long-standing tradition of excellence in teaching and research. Queens in comparison with some of the other Universities in Ontario and Canada as a whole has one of the highest number of residential students, and if not the top grades for entering students, certainly within the top two to three. Queen's is not a large cosmopolitan University such as the University of Toronto, or McGill, it is rather a mid-sized institution

It became apparent that for Queen's to continue to prosper and maintain its well deserved reputation for excellence in teaching and research, it would not be reasonable to attempt to emulate some of our larger institution, but rather define a niche where Queen's unique strengths and situation can be taken full advantage of. Two interesting and quite successful programs within the Faculty seemed to point the way. These programs, APSC100, TEAM/APSC400 led to the decision to pursue an Integrated Learning approach.

APSC100

http://civil.queensu.ca/apsc100/

For many years Queen's has had a common first year for Engineering students. In the past some aspects of this first year program seemed more effective at discouraging our students from pursuing the study of engineering that otherwise. Some three to four years ago it was decided to pilot a new program which at that point had the acronym QUFYAS, Queens University First Year Applied Science. The idea behind the program was to present the students with practical

engineering modules, rather than long tedious set laboratories. Although there were some inevitable "teething problems", the program was a considerable success. This program was expanded until now it is APSC100, Applied Science 100, and is offered to all first year students.

These projects are a quite eclectic lot being developed across most of the departments in the faculty. A typical project that was developed jointly between Chemical Engineering and the Chemistry Department is described. This particular project deals with a novel modification to the process for the manufacture of Bisphenol-A. Bisphenol-A is a high valued monomer used in the manufacture of Polycarbonate resins as well as Epoxy Resins. The traditional route to BPA as practiced commercially today involves the condensation of two moles of phenol with one mole of acetone. Unfortunately the reaction conditions and catalysts are such that the acetone can undergo side reactions, which will result in a significant make of refractory by-products that represent a process loss. It had been suggested that substitution of di-methoxy propane, for the acetone might significantly reduce the amount of side reactions and unwanted by-products.

The student groups, approximately 4 to 5 members per group, are initially presented with an overview of the various uses for Bis-Phenol A, some overall market and economic data, and additional information concerning the project. A teaching assistant drawn from our fourth year students is assigned to each project.

All participants in this course must have participated in WHMIS training. The groups are provided with appropriate laboratory facilities and are expected to design their experiments in order to test the hypothesis. In addition to the experimental facilities, the students must have their samples analyzed by Analytical Services and the Department of Chemistry using both GC/Mass Spec and NMR. They also have available some state of the art simulation software that they could use to confirm their experimental results.

The groups must make a preliminary presentation mid-way through the project, and then a final presentation as well as a final report. From our perspective the results to date have been most gratifying. Many of the presentations have been outstanding as well as their reports. Generally the students do develop a good understanding of the project, and often their reports challenge the quality that we expect from our fourth year students. The success of problem-based learning in diverse groups has certainly been demonstrated in APSC100. Student feedback has also been quite positive. The following are some verbatim comments and a poem from students about APSC100 and its predecessor QUFYAS.

> *"An Ode to QUFYAS*
>
> *Lectures and labs, day in and day out*
> *Is this what Engineering's really about?*
>
> *For an engineer is what I want to be*
> *And surely this requires more ingenuity*
> *Than the little wit and less creativity*
> *Required to cook a simple lab recipe*

Teamwork and problem solving are the things
That attracted me towards the Iron Ring
I want to learn to construct and create,
And know the satisfaction of a job done first rate

So much to learn with little confidence at heart
Hands-on work is the best way to start,
With help face to face with experienced T.A.'s
I can get the kind of education that really pays

At last, something exciting and new,
QUFYAS is a challenge that I can relate to
Shirking labs isn't my goal, Believe me sincere,
It's QUFYAS that would make me a true engineer!"

"Initially I was a little hesitant as to whether or not I should sign up for the QUFYAS Project. There were many obstacles that stood between my decision to apply for this course. I find chemistry and physics labs easy and straightforward. Therefore it seems foolish to sacrifice these marks. What if the projects are too difficult? What if I don't get along with my group members? What if I freeze during my oral presentation? Then, I remembered why I came to Queens. I was looking for an innovative and challenging academic environment. This course is completely different from anything I have seen in high school or university."

"The four of us (CG3) wanted to thank-you for your time and help this semester. We enjoyed having the lab at our disposal, as well as working on a real problem. Time spent with BPA was much better than time with blocks on ramps and their tendency to slide "

APSC400/TEAM

http://www.chemeng.queensu.ca/TEAM/

TEAM, an acronym for Technology, Engineering and Management is a fourth year program that involves multi-disciplinary teams of engineering, business and arts and science students. These students select a project from a list provided by industrial clients, and then prepare to carry out a consultancy for their clients. Although the majority of the students are undergrads there have been several occasions where we have had grad students participate in the projects.

In the fall term the students bid on a project of their choice, and upon formation of a team, they then meet with their team advisors and their client. Each team has an advisor mostly drawn from industry, whose role is that of a mentor and coach. These students are approaching the end of their undergraduate education and we believe that it is time for them to learn to stand on their own. The advisors are all senior professionals in their fields. Although different teams may require more or less support, the main purpose of the TEAM experience is for the students to

take ownership of their education via their projects. Each team must negotiate a letter of agreement, a waiver of liability, a confidentiality agreement, and in some instance an intellectual property agreement with their client. The students are expected to have all this in order before the beginning of the winter term.

In the winter term the teams carry out the necessary work in order to satisfy the commitments that they had made with their client. There is frequent contact with the client, and depending on the location of the client, visits to the client's site. We had one client in 2000/2001 who was located in Korea, another in Switzerland. Obviously it wasn't feasible in these instances to visit the client but contact was maintained electronically.

There are frequent team meetings with the course supervisors. We have all learned a great deal over the years since the advent of this program in 1994, students, advisors, coordinators and clients. Many of our clients come back year after year. One thing that we learned was that with the pressures of a fourth year program we were not able to completely stand back and expect the teams to keep up a necessary pace in order to accomplish their objective without a regular meeting schedule with the course coordinators. This is to be expected since the participants don't have much experience with project management. Development of project management skills is one of the major aims of the program, and although we do encourage the use of commercial software such as Microsoft Project, these regular meetings have proven to be very effective.

There is an obligatory mid-term presentation to the class as a whole at the University. This presents some interesting challenges since most of the projects are carried out under rather stringent confidentiality agreements. The final presentation is at the office of the client. The students also provide the client with a written report.

Funding for this program comes from client fees, University support and support from government agencies such as Materials and Manufacturing Ontario. It is obviously a costly program since there is a significant amount of travel involved. There are a lot of expenses involved in publishing of the final reports and some projects require significant analytical work.

The success of the program is measured by feedback from participants and clients. It is an essential that the coordinators of this program must be in constant contact with the industrial client base. From the feedback from clients we have concluded that in most instances the potential employer of our graduates makes the assumption that if he or she is a graduate from an accredited engineering program, the fundamentals should be in place. What they are now looking for are teamwork skills, inter-disciplinary experience, problem solving skills and the ability to participate in active learning.

"Fundamentals are essential but by no means sufficient"

One of the major difficulties that we encountered with TEAM over the years was a culture shock response by some students. Many students had never really experienced anything other that the traditional "chalk and talk" paradigm for most of their sixteen year educational experience. To be placed into a self-directed, problem based environment was a very difficult transition for

some students. With APSC100, and the introduction of more problem-based experience throughout the previous three years there seems to be a significant improvement in this regard.

One other problem is to do with the accreditation rules in Canada. The CEAB have a minimum path rule that states that a course will only be considered to offer students the minimum path that an individual can take in order to pass the course. This then brings up the issue of what constitutes "design". The course coordinators are career design and development specialists with many years of industrial experience. While we acknowledge the necessity of a discipline specific design experience for individual disciplines, we believe that the projects provided TEAM by industry represent a real design experience although it is unlikely that the project will ever represent discipline specific design exercises.

The very nature of the multi-disciplinary teams makes it virtually impossible to meet a stereotypical design criterion. We firmly believe that our responsibility as engineering educators is to provide a team experience with a high level of academic rigour, that has demonstrated an ability to produce emerging professionals with greatly enhanced ability to solve problems and pursue learning as active participants rather than passive.

The eclectic nature of the projects requires a great deal of "just-in-time" learning on the part of the participants. This learning takes place in the context of their projects and we are sure that it is retained to a greater degree than something taught in a lecture environment.

Our basic concern with narrow definitions of what constitutes design is in reality an attempt to measure success based on income rather than outcome.

TEAM has grown from a Chemical Engineering Course, to become APSC400, a faculty wide initiative. This simply recognizes what has been the reality for some time. Not surprisingly there has been a significant amount of resistance from some other departments in the faculty to have their students participate. A reason often given is the "minimum path" issue, however it is more likely that it is simply a question of "turf" and resistance to change. This is a well-recognized phenomenon in industry, a project that is developed in the "skunk works" is applauded provided it stays in the "skunk works". If this project should migrate into the main stream where it begins to have an effect on a broader cross section of people, then all the reasons why one can't participate begin to appear.

We hope to pursue this "minimum path" issue with the Canadian Engineering Accreditation Board. We were quite encouraged by a quote from George Peterson in the November 2000 edition of Prism, regarding Engineering Criteria 2000.

"EC 2000 encourages innovation and creativity with the assurances that well-planned experimentation will not jeopardize accreditation."

The Integrated Learning Initiative

http://ilc.queensu.ca/

Integrated Learning is a major new initiative in the Faculty of Applied Science that will dramatically enhance the delivery of engineering education at Queen's University. Integrated Learning combines a new learning facility with a strategically restructured curriculum to prepare graduates for the 21st century challenges and complexities of the engineering profession. The Integrated Learning initiative will transform engineering education at Queen's, and will position Canada as a leader, in engineering education worldwide.

A uniquely designed facility, the Integrated Learning Centre (ILC), will allow for the delivery of a redesigned curriculum that addresses new challenges facing engineering educators:

- **An exponential growth in knowledge.** An explosion of curriculum material and heavier course load has led to an increasing trend to specialization within engineering programs.
- **Desire for breadth and professional skills.** The tendency to specialize is in direct contrast to increasing demand by the profession for a strong foundation in theory coupled with the acquisition of the professional skills needed to be an effective engineer: critical analysis, effective communication and team skills, and a capacity for lifelong learning.
- **Need for integration across different disciplines.** The complexity of engineering problems requires an ability to work with and learn from engineers in other disciplines and specialties, and to acquire additional skills and knowledge in fields as diverse as business, policy studies, and economics.
- **Shorter Learning Curve.** An expectation that engineers will achieve full professional competence quickly. Fast-paced technology-driven organizations require graduates who are capable of tackling new problems and tasks with shorter training cycles.

Queen's is developing the Integrated Learning initiative as a comprehensive response to these unprecedented societal challenges. We will create a learning environment that will dramatically enhance professional skills and breadth of knowledge while preserving the core content (mathematical, scientific and technological) of the existing Applied Science program. From the moment they arrive at Queen's, engineering students will work intensively on team problems and projects, and by fourth year will be faced with real-world problems presented by industry and government. With innovations in curriculum, facility design, and program scheduling, we will deliver far more in four years than could previously have been imagined.

Vision of Integrated Learning at Queen's

Strategic Curriculum Reform:

The central element of the vision, is a totally redesigned curriculum across all disciplines of engineering. The core elements of a traditional engineering program will be enhanced through innovative delivery methods and active learning modes that integrate theory with practice. This approach has been most successful in APSC100 and APSC400 as described previously. The result will be engineers with an in-depth knowledge of theory, *and* with far superior professional skills. We have studied similar models world-wide (including Aalborg University in Denmark and University of Colorado at Boulder); the Integrated Learning model builds on the best elements of these innovative programs.

The redesigned curriculum encompasses three pillars of reform:

Team-based/Project-based learning: In the ILC, the faculty will act as consultants, advisors and coaches, while the onus will be on students and teams of students to direct their learning. There will be an emphasis on team-based, project-based learning to enhance communication and independent learning skills. Modularized laboratories will facilitate this, allowing multiple uses of the same space and encouraging learning beyond the time restraints of a traditional laboratory.

Integration across Disciplines: Traditional engineering education is structured by discipline. The ILC will move Queen's away from this "silo" approach and integrate the teaching of many sub-disciplines, giving students a wider understanding of the application of theory and more insight into other fields of engineering and science.

Links with Industry: Engineering education, like the health sciences and business, benefits from close contact with industry. The ILC will strengthen the bridge between the University and the external community, moving students steadily closer to professional practice over their four years at Queen's. By fourth year, students will be immersed in real-world projects, (APSC400) replicating the experience of professional practice.

A New State-of-the-Art Facility: To support this new curriculum, a new learning facility will be constructed where flexible structure and design will promote team-based and project-based learning, and will integrate engineering theory with practice every hour of the students' day. This learning environment will be intensely used and widely accessible, seven days a week. Traditional laboratory space will be replaced by project space where simulation, design, prototype manufacturing and presentation activities can occur. Other spaces will include team break-out rooms and seminar rooms.

The "live building" will be part of the learning process. The ILC will be fully instrumented to continually monitor every function of the building, including all elements of the heating, ventilation, power and communication systems. Structural elements and other building components will also be monitored through sensor devices. Data will be available on the internet, allowing Queen's students and high school outreach students from around the world to collect and analyze information.

Far-Reaching Benefits

The Integrated Learning Initiative offers significant and sustainable benefits to all of its users:

For Students: Enhanced capacity for lifelong learning; improved team skills; increased awareness and understanding of interdisciplinary issues; increased program relevance; improved career opportunities and greater knowledge of the workplace; well-developed set of professional skills; continuous program improvement.

For Faculty: Far superior teaching environment; new opportunities for collaboration with colleagues on curriculum development and course delivery; increased links with industry; greater staff support for developing new programs and learning approaches.

For Society: More broadly educated and job-ready engineers; a new model for engineering education with great transferability to other programs across Canada; expanded outreach programs to the community to showcase technology, and to attract young people to the engineering profession.

Summary & Conclusions

Many of the changes we envision have broad implications for the Canadian system. With the ambitious vision of Integrated Learning, Queen's is responding creatively to the challenges now being faced by all universities and educators. Graduating students will be better prepared for the workplace with a greater ability to adapt and respond to a dynamic and complex environment. The links between industry and academia will be strengthened through collaborative teaching arrangements and student teams focusing on "real-world" projects. As the needs of the engineering profession evolve, Queen's, through its Integrated Learning model, will be positioned to respond quickly and effectively.

The radical changes we are undertaking at Queen's are not without risk. While undergoing the process of restructuring the undergraduate curriculum, it is imperative that the University maintains its long-standing tradition of excellence in research. This will require a strategic management of the process in order to achieve our vision for the Integrated Learning Initiative without jeopardizing the research reputation of Queen's Faculty of Applied Science. However, we feel the risk is warranted because we do not believe that we can maintain the status quo and meet the evolving needs of our students, the engineering profession and society. In addition, we are building on existing strength – the Faculty has a common first year for engineering students, which provides a foundation for integration. The Faculty is small enough in size that we have a manageable group with which to work. We also have strong links with industry through, among other things, an award winning fourth year team project course APSC400.

Biography

Barrie Jackson

Mr. Jackson joined the Department of Chemical Engineering at Queen's University in 1998 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 contributions of the TEAM program to Engineering Education in Canada. Mr. Jackson is the current chair of the St. Lawrence Section of ASEE.