Experience of Partnering with Industry to Enrich Engineering Design Education

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Abstract
Involving industry in engineering design education would enhance quality of education and student experience as most design expertise resides in industry that can be accessed through guest lectures and interactions with students; and real, meaningful engineering design projects are needed for our students. Good industrial projects with enthusiastic industrial participation in the design capstone course would provide very valuable opportunity for students to gain meaningful experience and would prepare students better to be design ready engineers upon graduation. However, there are a number of challenges in association with industry participation. This paper reports our experiences in dealing with industry-based design projects as well as associated challenges. It is our experience and belief that these challenges can be successfully addressed if both university and industry treat the partnership from a long term perspective and provide reasonable resources to the partnership.

1 Introduction
The Canadian economy is continuously evolving to be more knowledge based and knowledge intensive. During the last two decades this evolution has accelerated through rapid technological advancements that are having significant impacts on industry and its workforce. Subsequently, the transformation of Canadian industry workforce is taking place from traditional resource-based and limited areas of manufacturing (such as automotive and aerospace) to a broad spectrum of knowledge-based workforce that must constantly innovate in order to stay competitive. To respond to the changing requirements, continuous professional development is demanded by industry and mandated by the engineering profession. Furthermore, engineering education in Canada has become more responsive and progressive in supplying qualified, innovative graduates to industry.

In the parallel to the technological changes in industry, the universities have also been evolving to cope with the rapid changes. One of the most noticeable changes in educational system is the wide use of the internet. The internet is used for most aspects of the educational system, from student services to enhancement of the educational content and learning environment. The programs, curriculums and detailed course materials are widely available in the Internet. MIT has made over 900 courses available free over the Internet and has plans to increase that to 1800 courses by 2008. Other universities in Japan, the US and other countries are following suit (MIT Open Courseware a and b). Therefore, the difference among educational programs, especially in curriculum and course content and in particular at the undergraduate level, is being gradually reduced. The competition to produce better engineers and innovators takes a form that cannot be simply measured by what are taught in the class rooms and associated text books. Given the importance of the engineering education system to industrial competitiveness, a new engineering educational model that emphasizes an integrated learning system based on design engineering has been proposed. It addresses the need for a fundamental shift from piecemeal learning of individual courses to an integrated educational method with an emphasis on curriculum, course content and teaching, inquiry based learning, and ability to apply learned knowledge to solve engineering problems, and practicing environment (Yellowley and Gu, 2004).

In the last two decades, engineering design content has been emphasized in undergraduate engineering curriculums and programs in Canadian engineering schools. This change is largely attributed to the Canadian Engineering Accreditation Board (CEAB). Many of the engineering schools currently offer final design courses where students either work
on design projects assigned by their academic advisors or ones supplied by industry, private or public organizations. The project course exposes students to real life, composite problems, which provide students with an opportunity to apply and integrate the knowledge acquired from several engineering sciences courses to real engineering problems.

2 Industry Involvement in Design Course

Design of products and systems take place on a regular basis in industry. Academics traditional undertake research, although some design and develop new products and systems that lead to patents and commercialization. Therefore, significant design expertise resides in industry. Since the late 1990s, the University of Calgary has partnered with industry to give students an opportunity to learn by solving real life problems in their fourth year capstone design course.

The course consists of two major components: lectures and team based design projects. The lecture component is focused on design processes and associated methodologies. The projects aim to provide students an opportunity to apply their knowledge acquired in their engineering courses to real life product and process design. Industry actively supports both components.

The course coordinator, as the senior member of the academic instructional team involved in this course, is responsible for the lecture content. This content consists of design theory and practical design considerations. The former is taught by the academic team. Industry guest lecturers bring real examples of design challenges. The topics covered by guest lecturers include: early stage technology, development and commercialization; peer review of facility design; human factors engineering; design considerations for fabrication and safety; and, design failure. In addition, non-engineering guest lecturers taught product liability and intellectual property rights. The experience with industrial guest lectures continuously improves and the content of their presentations has been better integrated with the theoretical component of the lectures. The response from students is very positive.

The major industry involvement is the supply of design projects ideas and the consultation with student teams throughout the two semesters of the course duration. The two primary benefits of industry participation are: providing real life experiences that motivate students’ learning through application of their knowledge to real problems; and learning from industry experts who are doing engineering design work daily. These industry experts also act as clients. However, it has been a challenge to obtain suitable industry design projects and successfully coordinate these projects with over 130 students and some 30 organizations annually. The challenges associated with developing, coordinating and conducting industry based design projects are discussed in the following sections.

3 Design Projects and Student Teams

3.1 Defining Project Requirements

Before seeking the actual projects, it is important to have a clear idea of what makes a good design project for fourth year mechanical or manufacturing engineering students. It is easy to identify the technical skills that these soon to be engineers possess. The softer questions are more challenging. For example:

Is this project clearly defined?
- Should the project be clearly defined or is that something that is actually part of the design process?
- Without a clear definition, can the course coordinator determine if the project is suitable?
- What and how many different engineering aspects should a project incorporate?

Can this project be accomplished?
- Time
- Student knowledge base and skills
- Cost

What is the commitment of the industry partner?
- Availability to provide information to the team?
- Financial Support
- Access to information, data, or facilities?

What are the IP concerns of the industry partner?

Although student teams possess good basic engineering knowledge, it would not be productive if the project requires significant in depth knowledge in a particular field. For example, design of a new control system with state of the art control technologies would impose a situation where student teams spend significant amount of time in learning advanced control theories and new technologies rather than design of the control systems.
The complexity of the project influences the time required. Thus, the project scope must reflect that the course is two semesters and 6 credits with a team of 3-5 students. They need to produce the expected deliverables within this time frame.

Accurate cost assessment prior to initiating the project enables the course coordinator to evaluate and secure the necessary funding from the industry partner and/or the university. The student team must then manage the budget and maintain suitable cost controls. This avoids a prematurely abandonment of the project due to lack of funding or cost overruns.

Clear expectation and scope definition before the course coordinator accepts a project goes a long way to ensuring a successful project and a rewarding experience for the students and the industrial partner. However, between spring when the industry partner suggests the project and late September when the first meeting with the team occurs, the partner may want to revise the scope. This reflects real life design challenges. When this occurs, close supervision is required from the course coordinator to ensure that the scope is redefined in a timely manner, still meets the course objectives and that adequate funding is available. This will reduce frustration for both the student team and the industry partner.

### 3.2 Finding Design Projects

Until a reputation is established, the course coordinator has a difficult job soliciting projects. At the University of Calgary, letters are sent to industrial contacts and followed up with personal calls asking for participation. Friends and business associates are also contacted to ask for projects and/or leads. Typically, additional projects are required and cold calls are made to manufacturing and engineering firms in Calgary. Not-for-profit organizations are also contacted as physically and mentally challenged individuals often require custom designed devices. Emails were sent to the internship students that will be returning to classes in the fall to encourage them to provide contacts in the companies that were working for and/or to suggest projects.

In 2003, over 200 calls were required to get thirty projects. The most common question was “who are you again?” Obviously, as the program continues and awareness grows, it will be easier to obtain projects. In 5 to 10 years, this year’s graduates will be in a position to give back to their alma mater by providing projects.

Getting a commitment from a company to provide a project is a classic catch 22. The busier the company the more they can benefit from a group of enthusiastic students to work on a design project that is lying dormant because the company is too busy. However, if the company is busy they are reluctant to devote any manpower to sponsor the project. Typical reasons for not providing a project for the coming year were:

- Last year’s sponsor was no longer with the organization.
- The results of last year’s project were still being evaluated.
- Too busy
- Concerns about Intellectual Property
- Could not think of a suitable project.

The first three are difficult for the course coordinator to address, but having a concise answer about Intellectual Property as has been developed for the coming year of the program can quickly resolve this concern. The development of the criteria for a suitable project as well as examples of previous good projects, help the industry representative to develop project ideas for the coming year.

The future success of the program is like any venture – deliver a successful project and build the department’s reputation, then companies will respond positively and seek out the university to offer ideas, time and money.

### 3.3 Student Team Selection

Creating a good design team is a process of part selection and part leadership. Two different approaches have been tried and each has its pros and cons. Both methods result in some teams working on a project that was not their first choice, but that is real life.

1. Student selected teams. Typically, student selected teams have members that have previously worked together. They usually have the similar grade and workload expectations and often have a recognized leader. However, they tend to lack cultural and sometimes gender diversity. Occasionally, the team can not agree on the project they want to apply for.

   People tend to like working with others that are similar to themselves. All students complete the Myers-Briggs personality test. On one team, each member was a “perceiver”. During the concept stage they generated 50 ideas that they thought were worth pursuing but struggled in reducing the list to a reasonable number to evaluate. At the entire other end of the spectrum, one team saw no need to brainstorm as they already knew the answer.
Student selected teams seem to have less internal strive that the course coordinator is required to address. However, in the workplace, one usually does not get to select his/her team members.

2. Course coordinator selected teams. The course coordinator provides a list of design projects to students. Students are required to apply for a specific project by stating why he/she wants the particular project and how his/her skills and interests align with the project. Based on the applications, the course coordinator assembles the teams. These teams have different dynamics and potentially more internal conflict than student selected teams. The administrative aspect increases from the number of teams to the number of students as the course coordinator attempts to satisfy the requests of each student.

Teams that have a vast range academic achievement find the work load unevenly distributed. When the GPA of individual team members varies from 2.0 to 4.0, often the better student(s) assume a disproportionate share of the workload in order to achieve the grade they want in the course. In one insistence, when the peer review was completed, one team member was singled out as not contributing. That individual in turn accused the other team members of not assigning any work to him. The quality of this individual’s work did not meet the overall team’s standard so they just did not give him anything to do.

Team selection needs to reflect the objectives of the course. The need for conflict resolution will likely be lower in student selected teams but overall, diverse teams have better solutions and conflict resolution is a very real part of design teams.

3. Conflict resolution. Conflict occurs among student team members, especially on teams selected by the course coordinator. Taking a proactive approach to conflict resolution is the best idea. It is beneficial to:

- Build material on organizational behavior into the design course.
- Have the students pre-think how they will handle different situations.
- Incorporate a lesson on active listening and proactively expressing your concerns.

These are valuable life skills. In addition, the course coordinator needs to be prepared to discuss with individual team members his/her concerns about the team dynamics and peer grading.

Regardless of the method for team selection, getting the project the student wants is his/her top priority. Some projects are highly sought and other projects have few or no applicants. Students pointed out, they pay for the course so they should get the project they want. Too bad real life design is not like that!

4 Challenges and Experience

Students, industry partners and the course coordinator can all have different perspectives regarding course deliverables. The design project course is not an engineering design company. Students learn the design process and may not necessarily deliver a final design and/or prototype to the partner. From industry’s perspective they are looking for a finished project.

4.1 Intellectual Property

Everyone knows something about Intellectual Property (IP) but few people understand what qualifies as IP. Ideas are important but are not defendable as intellectual property. It is beyond the scope of this paper to discuss IP; however, within the framework of a design course with industry partners this question needs to be concisely answered.

The first question that a company representative asks is “who owns the intellectual property that arises?” When soliciting projects, telling the representative that it is unlikely that the work will result in the development of any intellectual properties leaves him/her questioning exactly what will be accomplished. Many of the project ideas have potential so the representative is justified in asking the question. However, the vast majority of the projects are either for unique or small niche markets making the IP unlikely to be exploited by others.

In addition, ensuring confidentiality within a classroom is not feasible. Teams are required to make presentations that put the idea and design work in the public arena. This makes it impossible protect any IP.

The question also arises of responsibility of the university and student. The university has a responsibility to protect the rights of the students. The course is required to complete their degree. The industry partner is not signing a research contract and can not truly be considered a client as there is no obligation to deliver a completed project, thus often their IP expectations conflict with reality. At the University of Calgary, the administration has traditionally wanted the students to own the IP rights. The industry partner would then have the first right of
refusal to license the technology. If the license is a lump sum, then administratively it is not too difficult, however, royalties would require locating and tracking students, possibly for years after graduation and issuing annual cheques. This concept creates tension with the industry partner and time consuming paper work for the university and frequently the industry partner’s lawyer.

The university has recently softened their position. For 2005/06, the industry partner will be able to retain the IP provided the students are willing to sign their IP rights over to the company. Students are very suave and will also question the wisdom and implications of doing this. Students unwilling to relinquish their IP will have to select projects that do not involve IP considerations.

The following are some examples of IP considerations that have arisen in the course.

One student had a job offer from a company that built commercial versions of the device that his design team was working on. He was concerned about the knowledge that he obtained during the design course and who had the rights to this information.

In another case, the issues around IP prevented the industry partner from supplying crucial information until the second term of the project. The team was frustrated with the course coordinator for not having this resolved prior to the start of the course; angry with the industry partner for being inflexible; ineffective in the first term and struggled to complete the related assignments; and, overwhelmed getting the project completed in the second term.

IP needs to be addressed in early discussions with the industry partner and before assignment of the projects with the students. All paper work has to be signed off within the first two weeks of class. In the Department of Mechanical and Manufacturing Engineering, where there are over 130 students and 30 projects, this is time consuming job at a time of year that is already very hectic. In order to ensure that this is completed in a timely fashion, student assessment must to be tied to this paperwork.

4.2 Cost

Design courses require relatively large resources compared to other courses. These resources include the course coordinator, administrative, technical advisors, academic advisors, prototype materials, shop time and technician support. At the University of Calgary, there is a course coordinator plus up to 8 academic advisors. Although there is no direct cost associated with assigning the academic advisors there is a challenge with teaching load allocation.

Having sponsorship from the industry partner can help defray the costs associated with materials required for prototype construction, travel to site and/or telephone charges. Furthermore, paying assigns value and helps in establishing a commitment. It also establishes expectations. Referring to this as an administration or registration type of fee reduces those expectations. Some organizations see their participation as sufficient since a engineer will be committing time and they view the cost of undergraduate education of the responsibility of the government and the student. Determining the right amount is a fine balancing act and varies between industries, companies and organizations.

4.3 Scope Creep

Almost every project is subject to scope revisions. Dealing with this within the framework of a design course is challenging. The real world charges a premium for work order changes. This ensures that the client carefully evaluates the implications but there is no such feedback loop associated with design course projects.

Defining scope is an important aspect of design. Between the commitment by the organization and the start of the course there have often been changes within the organization or the business environment that result in scope revisions. Teams should review and refine the scope with their industry partner. The course coordinator needs to review any scope modifications with the team and the industry partner to ensure that it is achievable and that it meets the requirements of the course.

Scope changes are not always bad. One team was designing training wheels for a mountain bike for someone with balance problems. Half way through the course, the partner decided that a recumbent bike would be a better solution. The team rose to the challenge, designed and built the bike.

Helping the teams manage the scope changes requested by the partner is an important role for the course coordinator. The course coordinator or his/her designate need to stay abreast of these revisions as they occur.

5 The Role of the Course Coordinator and Industrial Partner

The role of the course coordinator has varied over the years. It has ranged from the coordinator or his/her
designate, attending all the meetings between the industrial partner and the team to a very hands-off approach where experts gave the lectures and the course coordinator did not get directly involved with the individual projects. There are lots of ideas around the best way to manage a course of this type. The following are resources that need to be available to the teams:

- Technical support
- Progress monitoring along with timely feedback on the work
- Assistance in managing the difficult industrial partner
- Assistance in conflict resolution within the team
- Technician support as required for prototype construction

In many ways the fourth year capstone design course is like managing a diverse engineering company. There are many different teams that are working on specific projects. They need oversight from senior management to ensure that the project scope is well defined and that it will be completed on time and within budget. The teams need to have access to technical experts in engineering as well as the resources needed to build prototypes.

The ideal partner commits to meeting weekly or at least bi-weekly with the team. This forces the team to continue to make progress. It is like a project management meeting where the work to date is reviewed, the way forward is discussed and the challenges clarified.

The partner should not see themselves as only a client as the probability of producing a finished functional design is actually small. However, often the request to participate is pitched as an opportunity to get some “enthusiastic fourth year engineering students to work on a project that is languishing for lack of time.” Other possible projects include the current projects being carried out at the company and they can be pursued in parallel by student design teams. Either way, the company sees that there may be a benefit to them from participating.

Ideal partners are very keen to enhance engineering education and have significant industry experience as engineers and managers in their organizations. They are willing to take on a mentoring role.

6 Summary

Industry involvement in design course is essential for two basic reasons: 1. most design expertise resides in industry, which can be accessed through guest lectures and interactions with students; and 2. real, meaningful engineering design projects are needed for our students to work on.

When selecting industry-based design projects, one should keep in mind that the capstone design project should provide an opportunity to allow students to incorporate many technical aspects of previous courses and to practice non-technical skills as well. It should simulate the open ended design problems that engineers face and allow students to independently seek solutions. Good industrial projects with enthusiastic industrial participation in the course would provide very valuable opportunity for students to gain meaningful experience and would prepare students better to be design ready engineers upon graduation. However, it is not a hands-off project for the course coordinator and industrial experts. Upon graduation these engineers will be supervised by senior engineers, they will have the support of administrators and senior managers to assist with legal, personnel and client challenges. There are a number of challenges in association with industry participation that can be successfully addressed if both university and industry treat the partnership from a long term relationship perspective.

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8 References


