The UBC Chair in Design Engineering – Breaking Out of Disciplinary Silos

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Abstract

UBC was recently awarded an NSERC Chair in Design Engineering (CDEN). The focus of this chair is addressing the problem of 'disciplinary silos' in engineering education, primarily through enhancing cross-departmental and cross-faculty initiatives. Our principal initiative is a multidisciplinary senior design course which will bring together engineers from different departments in a year-long project sponsored by external clients. We will also establish a new building – the $6.6M Wayne and William White Engineering Design Centre – which will serve as the focal point for faculty-wide design activities.

1. Breaking Down the Silos

The focus of the recently-awarded NSERC Chair in Design Engineering at UBC is addressing the problem of 'disciplinary silos' in engineering education [1]. As is the case in many engineering schools around the world, the University of British Columbia's engineering activities are divided into departments which have considerable autonomy in how they conduct their activities. The accreditation process serves as one mechanism for introducing influences from other universities and from the profession at large, but there is surprisingly little communication between departments, especially at the level of undergraduate education. At UBC in particular, there are widely varying requirements and expectations for what occurs in our various senior design courses. For example, mechanical engineering offers a team-based design experience with 4-5 student members per team, dedicated faculty supervisors responsible for 4-5 teams each, external clients, and industrial mentors, and offers a dedicated workspace and shop access for project students. In electrical and computer engineering, students typically work in pairs on research or design projects, and the projects are supervised by individual faculty members who offer the projects. In civil engineering, students take a 3-credit senior design course taught in a specialized design studio which offers facilities for team-based work. These arrangements have evolved over time in the various departments, and, while it is no doubt convenient from a variety of administrative, cultural and scheduling perspectives to restrict student projects to the boundaries of a single department, in real practice most industrial products require contributions from many disciplines, integrating electronics and computers with mechanical devices, and interfacing with biological or chemical processes. Therefore, a multidisciplinary approach in design education is critical to preparing our students to enter the workforce where they will be required to collaborate with people from various disciplines.

Other symptoms of this 'disciplinary silo' problem include:

- **The lack of dedicated resources.** Students involved in interdisciplinary projects currently find it difficult to get access to all the support they need in terms of mechanical shops, computer labs, and electronics shops, etc., and they often lack access to studio space since any that exists is typically tied to a given department.

- **Inconsistent messages about design engineering.** Each department in the Faculty, and even in some respect each course, is relatively free to define design in its own terms, and to use its own processes, tools, methods and criteria. As a result, from the students’ perspective, the concepts and approaches used in design appear to be fuzzy and are therefore often ignored.

- **Limited dissemination of evolutions in engineering design and practice.** The traditional definitions of engineering and of design have been challenged in recent years to take into account emerging disciplines (environmental engineering, software engineering, etc.) and new approaches to evaluating the choices we make – e.g. sustainability, value to stakeholders and “Triple Bottom Line” accounting (financial, environmental and societal tradeoffs). Disciplinary silos limit the diffusion of
understanding as to how to best address these issues in student design experiences.

We believe that the major challenges to giving our students this kind of multidisciplinary experience are primarily related to organizational and cultural issues within the University. Few mechanisms currently exist to coordinate efforts across various faculties and departments and to provide students from different departments opportunities to work with one another.

The physical resources of the university are distributed across the faculty. As a result, even when one department acquires a useful piece of equipment, such as a waterjet cutter, there is no mechanism for this to be made available to students from across the faculty.

2. Activities of the Chair

The primary purpose of the Chair is to develop a cross-departmental design community in the Faculty of Applied Science at UBC in order to allow students to function effectively in the kind of multidisciplinary design teams that they will practice in their professional lives, which are crucial to creating new technology-based entrepreneurial ventures in the future. To build this cross-department design community, it is necessary to ensure that professors in more than one department are committed to the proposed curriculum and organizational initiatives. We have set up a dual chair structure consisting of a Senior Chairholder and an Associate Chairholder drawn from the two largest departments: Dr. Philippe Kruchten from Electrical and Computer Engineering and Dr. Antony Hodgson from Mechanical Engineering (see section 4). A dedicated Instructor in Design Engineering and a Designer-in-Residence will further support these two Chairholders in achieving specific program goals (see section 2.2).

The principal initiatives through which we propose to develop this cross-department design community are the following (in order of priority):

1) Establish cross-department and cross-faculty projects. This initiative connects the two largest departments (Electrical and Mechanical) by bringing together senior students from both departments in a multidisciplinary capstone design experience which builds on our successes in the 4th year Mechanical Engineering program and the New Ventures Design course initiated by Dr. Peter Lawrence, the recent Chair in Design Engineering at UBC. As described below, this course will initially focus on medical devices as a particular broad area that requires multidisciplinary approaches and one that is strongly supported by local industry.

2) Extend interdisciplinary capstone projects to other departments. We will then extend the initiative to include the departments of Chemical and Biological Engineering and Material Engineering through significantly expanding the design project elements of the existing Applied Research and Development course in the graduate Biomedical Engineering program; this will be synergistic with the first initiative because the application area is the same and we can build on the same external relationships developed through the first initiative.

3) Unify exposure of students to key engineering design and project management concepts across the Faculty. This will be achieved through establishment of shared physical facilities such as a prototyping shop and equipment, design studio spaces, student project rooms, space for extracurricular design competition teams, many of which will be housed in the Engineering Design Centre. The initiative will also be enabled by developing a faculty-wide design interest group, and by encouraging new faculty to establish connections to and gain exposure to local firms. It will also be supported by the development of common teaching materials, definitions, and examples for engineering design, to be made available to faculty through the Centre for Teaching and Academic Growth.

4) In the second half of Chair's term, we will draw in and integrate the two remaining engineering departments, Civil and Mining, by expanding the theme of the senior projects to include sustainability.

2.1 Theme of the Chair

The area of medical and assistive devices and technology is a fertile source of multidisciplinary project possibilities at both the undergraduate and graduate levels that can offer opportunities suited to students in at least four major departments: mechanical engineering, electrical and computing engineering, chemical and biological engineering and materials engineering. Many such projects are possible in areas ranging from assistive and rehabilitation devices to diagnostic and therapeutic devices. This theme has numerous other strengths:

- Students are attracted by the human aspects of these problems.

- A number of medically-related non-profit groups such as the Amyotrophic Lateral Sclerosis Society and the Tetra Society recognize a need for engineering design assistance and are actively seeking collaborative project opportunities and are providing funding.
It is of great interest to numerous companies affiliated with the BC Medical Device Industry Association (now part of BC Life Sciences) and/or the Medical Device Development Centre (a small company incubator).

2.2 Principal Initiative: Multidisciplinary Senior Project Course

Our principal initiative builds on the recent full-scale rethinking and redesign of the fourth year mechanical engineering capstone design projects by establishing a faculty-wide multidisciplinary, year-long capstone design project (APSC 496: Interdisciplinary Capstone Project), which will see teams of 4th-year students from 2 or 3 engineering disciplines work jointly on design projects, each in association with a local industrial partner who will serve as a client for the teams. The design projects have faculty advisors from each appropriate department from which students originate. The Chairholders define a range of projects in the spring and summer in collaboration with the industrial partners, and match students from different departments to form project teams in the fall. Part of the Chair’s activities and resources will be dedicated to supporting these projects by providing adequate design studio space and funding for materials, although companies will also be expected to contribute. At the end of the projects, students present their project to a panel comprised of faculty members from various disciplines and industry representatives and in a public project fair.

Example Projects. The kinds of projects we envision are new products which would require involvement of multiple disciplines would be suitable for student projects. Two examples of projects we have recently offered are:

1. Ventilator for ALS Patients to Permit Speaking:
   During the later stages of the disease, a person with Amyotrophic Lateral Sclerosis develops difficulty in breathing and may be put on a ventilator, which hampers verbal communication. A mask with a microphone only solves part of the problem, and a smarter solution is a system to process the sounds, eliminating the noise of the forced ventilation, and, in later stage of the disease, even improving the quality of the speech, and provide voice-activated control.

2. Responsive Environment for Person in Wheelchair:
   When a person confined to a wheelchair moves around in a house or office environment, wireless sensor technology, which is sensitive to the person’s presence or to certain movement patterns, can be used to help the person take actions such as adjusting light and temperature, opening doors, activating kitchen or entertainment devices, etc.

These projects have multiple facets: mechanical, materials, sensors, signal processing, wireless communication, software, interfaces with other equipment, and safety – and can potentially be decomposed into two or more sub-projects.

Learning Goals. The learning goals of these projects are primarily focused on interacting with potential users and identifying their needs, developing experience with industry-standard design processes, creating and testing prototypes, and working productively in multidisciplinary team settings.

Significant emphasis is placed on:

- interacting with both users and clinicians to define the problem and assess existing solutions

- identifying the value proposition and the overall marketing approach (ie, who will pay for the solution)

- project planning - laying out a reasonable timeline, identifying and assigning responsibilities for different tasks to different team members.

- interface definition - explicitly identifying and documenting how each member's or sub-team's responsibilities connect with those of the other members or sub-teams.

- development and use of proper project documentation - students will be acquainted with ISO 9000-type quality control regulations and will use similar (simplified) versions of these regulations in their own projects.

- familiarization with the use of standards and associated regulatory and liability considerations.

- regular team communication - use of concurrent engineering approaches to ensure that issues relevant to and with implications for other team members are identified early and communicated clearly both amongst the team and to the faculty advisors and clients.

- familiarization with key prototyping technologies relevant to each discipline. For mechanical engineers, this might involve rapid prototyping processes such as water-jet cutting or stereolithography machines; for electrical engineers, this might involve working with FPGAs or CAD-based circuit designers and simulators.

- quantitative reasoning - an emphasis on the use of prediction early in the design process, based on
analytical models, simulations, experiments or prototype development and testing.

**Course Structure.** The course is structured using a consulting company model: each professor involved (called the supervisor) is responsible for several (4-6) engineering (student) teams, typically consisting of 4 to 6 students, drawn from different disciplines. Each team also has an industrial mentor who will provide students with an industrial practice perspective that complements the input from the academic project manager. Design teams meet both individually with the manager and mentor and (typically biweekly) with the other teams in their division; this additional peer check-in provides strong incentives for individual teams to keep up with the other teams in the class and minimizes 'drifting'. There is a strong expectation that teams will produce their first comprehensive prototype by February so as to have time to incorporate feedback from the client in time for the formal end of term presentation and delivery to the client in early April. In addition to the small group meetings, there are weekly meetings of the whole class to offer students additional exposure to selected topics in the practice of design, as well as opportunities to hear guest speakers from industry. This course structure combines and builds on the most successful features of the Senior Capstone Course (MECH 457) led by the associate Chairholder and the New Ventures Design course (APSC 486) developed by Dr. Lawrence.

**Student Evaluation.** Numerous elements of the students' performance related to process, product and competence are evaluated. Students are required to maintain formal logbooks and submit weekly progress updates and monthly 'stage reports'; each stage report has its own specific focus appropriate to that stage of the design and instructions to the students are modeled on documentation typically produced in the course of industrial design projects. These reports are evaluated both for process and technical competence (e.g., in analysis and prototyping) by the supervisor, the mentor and the client. The product itself is evaluated by these same people, as well as by visitors from elsewhere in the university and from industry during our annual project fair. Competency in oral presentation is developed through requiring each student to participate in two separate oral presentations (explicit training in oral presentation skills is provided in several earlier courses).

**Infrastructure and Design Instructor Position.** A considerable effort is required to create and operate a cross-faculty infrastructure that will support these multidisciplinary project students. We will shortly be hiring a full-time Instructor in Design Engineering (IDE) to be responsible for coordinating and administering the day-to-day operations of the facilities associated with the Chair, including specifying and acquiring equipment, scheduling student access to the various resources available and allowing students from across the faculty to gain access to intra-departmental resources.

**Intellectual Property Issues.** In the past, intellectual property issues have proven to be a significant impediment to securing project opportunities from local companies. Dr. Lawrence negotiated a major change in how the Industry Liaison Office treats such issues that has proven to be acceptable to most of our planned industrial partners; this has taken the form of a much simpler 'ready-made' agreement that allows companies to retain access to the intellectual property developed in the course of the project. We will refine this framework to minimize any remaining concerns.

### 2.3 Promoting Design Thinking Across the Faculty

Solely focussing on capstone projects will not be sufficient to instil a *design and innovation spirit* in our engineering students. We are planning to promote design across the Faculty and the University through establishing a faculty-wide Engineering Design Committee chaired by the Senior Chairholder to initiate discussions amongst all faculty members who are responsible for teaching design. We will seek opportunities to share teaching materials and approaches and will participate in design-related curriculum development activities in all departments in order to identify potential synergies.

### 2.4 Graduate Education

Currently, we have approximately 30 graduate students enrolled in our biomedical engineering program, with about 10-15 joining the program each year. These students take a lab/project course, taught jointly by UBC faculty and faculty from the industrially-focused biomedical technology program at the BC Institute of Technology (BCIT). The project portion of this course has been largely based on faculty-supervised projects proposed by the student and has not explicitly required the student to apply the processes and knowledge gained from other courses in the program; indeed, not all projects have been design projects – some have been modeling or experimental in nature.

We will gradually convert this course into a multidisciplinary project course in which students from more than one engineering discipline work with both a local industrial partner and a clinician to design a device or process which has commercial potential. The overall timeline will be similar to that of the
interdisciplinary capstone project and students will have access to the same design studio facilities available to the senior undergraduates. This will provide significant leverage of the Chair’s investment by explicitly connecting the Chair to the industrially-focused faculty from BCIT, which will enable us to tap their networks for project sponsors.

2.5 Continuing Professional Development
As the Association of Professional Engineers and Geoscientists of BC (APEGBC) has established mandatory reporting of Continuing Professional Development (CPD), a need will arise for engineers to expand or refresh their knowledge, without embarking on a degree program. The Chairholders are engaged in a discussion with APEGBC and the UBC Continuing Education in how to provide professional development courses to practicing engineers with a view towards targeting a subset of the curriculum for the M.Eng. in Biomedical Engineering to this population as a certificate program.

3. Facilities & the New Engineering Design Centre
There are several facilities currently available in the Faculty in support of the chair activities:

- A student mechanical workshop housed in the Mechanical Engineering building – equipped with a rapid prototyping machine and staffed with a dedicated teaching supervisor.
- A mechanical and electronics workshop located in the Electrical Engineering Building, equipped with a water cutter useful for prototyping projects.
- The Ken Spencer Project Room in the McLeod Building dedicated to the students’ projects in the New Ventures Design course. There is also a wide range of student project rooms in this building.
- The PACE Laboratory in the ICICS Building, which is a computer laboratory with access to a variety of engineering and design software. There is a student project space on the ground floor of the building, and it provides a variety of computing and video equipment that can be accessed by student for projects.
- A workshop for graduate students participating in multidisciplinary projects, located in the AMPEL Building.

In addition, in the fall of 2009 will start the construction of the $6.6M Wayne and William White Engineering Design Centre (EDC) that is expected to raise significantly the profile of engineering design across the Faculty and the campus, and with our various stakeholders (see figure 1). In addition to student study spaces, the facility will also provide spaces for direct instruction, support of extracurricular activities and learning skills development. This project is intended to include the following four key elements (see figure 2):

- **Engineering Design Studio.** Design studio space to enhance delivery of engineering design courses, students’ engineering design activities and collaborations across all engineering disciplines.
- **Project and Design Teaching.** Instructional spaces for project and design teaching, including a project room and a computer / reading room for design projects.
- **Student Workshop and Team Competition Space.** One of the Faculty’s priorities is to support design through student-directed teams, competitions and related extra-curricular activities. The student-administered workshop and its facilities will support student-directed teams, competitions and related extracurricular activities.
- **Computer and reading room** with workstations.

The building also hosts the engineering co-op offices. The Senior Chair will be the director of the Engineering Design Centre, and this centre should become the hub of the faculty's design activities and will serve a major role in coordinating access to the various design and fabrication resources currently distributed across the various departments.

4. Chairholder Biographies
To achieve these interdisciplinary goals, we have assembled an interdisciplinary team. The chair has two holders:

4.1 Philippe Kruchten, Senior Chairholder
Dr. Kruchten is a Professor in the Electrical and Computer Engineering Department of UBC. He is a mechanical engineer by initial training, who went on to designing large scale, software-intensive systems in the areas of telecommunications, defence and aerospace with Alcatel, Rational Software and IBM, both in Europe and North America. He was the lead software architect for the Canadian Automated Air Traffic System. Based on his experience, he developed and commercialized the Rational Unified Process® for software development. He joined UBC in 2004 to lead and further develop the Software Engineering option in ECE.
4.2 Antony Hodgson, Associate Chairholder

Dr. Hodgson is a Professor in the Mechanical Engineering Department and has research interests in computer-assisted surgery, medical robotics and human motor control. He collaborates extensively with orthopaedic and laparoscopic surgeons, as well as with specialists in rehabilitation sciences, kinesiology, computer science, electrical engineering, educational psychology and dental surgery. Several of his technologies have had patents issued or applied for, and he is currently pursuing the commercialization of a smart steering device for intraoperatively guiding a C-arm fluoroscopy machine. Dr. Hodgson also sits on the board of the Medical Device Development Centre, a local medical device company incubator.

References