Integrating Industrial Experience into the Undergraduate Engineering Curriculum Using Case Studies

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ABSTRACT

A case study on the design and implementation of a program to use case studies to integrate engineering practice across the Engineering curriculum at the University of Waterloo is presented. A key innovation of this program is the generation of case studies directly from student experience, via conversion of their co-op work term reports into case studies. The principles and practices used for this program are presented, along with a discussion of the successes and issues.

Keywords: Case Studies, Engineering Design, Engineering Education, Co-operative Education

1. INTRODUCTION

Context

The vast majority of the programs at the more than 40 Canadian Engineering Schools are accredited through the Canadian Engineering Accreditation Board (CEAB) [1]. Accreditation ensures that all engineering students have the necessary technical knowledge based on the specification of minimum levels over broad categories including math, science, engineering science, and complementary studies. This means that students who graduate from an accredited program are eligible for registration as professional engineers after a minimum level of postgraduate work experience, and the completion of only a separate professional practice and ethics exam. Recently, the CEAB has moved to an outcomes-based accreditation [2], while still maintaining minimum levels of knowledge based on inputs. This has included a more explicit recognition of the necessary professional skills, as outlined in the required graduate attributes, Table 1. This accreditation process results in relative uniformity across programs in Canada, but still provides flexibility for innovation within individual programs.

Programs evolve, and over the past 20 years there has been an increasing recognition that this evolution has had a bias towards accommodating more engineering science. To balance this, there has been increasing emphasis on practical engineering skills, especially engineering design. In Canada, this has been addressed through changes in the CEAB accreditation rules, the advent of national associations such as the Canadian Design Engineering Network, now evolved into the Canadian Engineering Education Association [3], and the NSERC (Natural Sciences and Engineering Council of Canada) Chairs in Design Engineering program [4].

Table 1: CEAB Graduate Attributes [2]

1	A knowledge base for engineering	7	Communication skills
2	Problem analysis	8	Professionalism
3	Investigation	9	Impact of engineering on society and the environment
4	Design	10	Ethics and equity
5	Use of engineering tools	11	Economics and project management
6	Individual and team work	12	Life-long learning

The University of Waterloo has the largest engineering program in Canada and the largest co-operative education program in the world, with 100% of engineering students participating in the co-op program. Co-op has been a part of the engineering program since its inception in 1957, and as a result is an integral part of the culture at Waterloo. This co-op experience complements students' academic studies, which have a strong basis in mathematics and engineering science, comfortably exceeding the CEAB minimums across all programs. The academic year is divided into 3 4-month terms, starting in September, January and May. Students typically alternate co-op and academic terms, and receive 24 months of real-world experience prior to completing their otherwise standard 4-year undergraduate program.

Students are expected to develop professional engineering skills on their work terms, although their individual experience will be quite variable. In 3 of their 6 work term opportunities, students are required to prepare a work term report, documenting a project that was completed over the term, to reinforce their learning. These reports are marked for academic credit, and returned to the student.

Motivation

Waterloo has strong engineering programs and attracts strong students. Most of our programs have a strong emphasis on engineering science. Anecdotal feedback from employers and our own experience suggests that students are very strong analytically, but have some difficulty with open-ended problem solving and design. Some students have difficulty making the connection between real situations and abstract models.

Feedback from co-op employers suggests a few specific areas of improvement including professional skills such as communication and teamwork, problem solving, and design. At the same time, there has been some concern regarding the lack of opportunities for interdisciplinary experience; there is relatively little formal collaboration between Departments outside of first year and the extracurricular student design competition teams.

Improvements to the overall program can occur through the co-op system or through the curriculum, but perhaps the most potential lies in areas integrating the two. One such initiative is the advent of a professional development program [5], wherein students take online courses during their work terms to improve professional skills. Another opportunity is to increase the number of real-world examples used in the curriculum, so that students can experience the natural complexity and interdisciplinary nature of engineering practice in a controlled environment, to develop engineering judgement, problem solving and teamwork skills, and then hone those skills in the workplace on subsequent co-op terms. One practical challenge with this objective is the generation of a sufficient quantity and quality of engineering case studies, at the right level of sophistication and appropriately presented. This challenge has been met at Waterloo through the creation of the Waterloo Cases in Design Engineering (WCDE) Group (www.design.uwaterloo.ca), which creates case studies from our own students' experience, primarily through conversion of work term reports.

2. WATERLOO CASES IN DESIGN ENGINEERING

WCDE was created as part of the NSERC Chairs in Design Engineering program: to systematically develop and implement case studies throughout the engineering curriculum. A key innovation is the development of case studies from students own experience, primarily on work terms. WCDE was created through the NSERC – General Motors of Canada Chair in Collaborative Design, running from 2004 to 2010. This start-up phase focused on developing the infrastructure to develop case studies from student work reports and implementing them in class. The program was renewed for 5 years, 2011-2015, as the NSERC-Waterloo Chair in Design Engineering, with a wider consortium of Industry partners. This current phase is focused on maintaining a consistent production rate of cases and broadening the implementation experience. The goal at the end of this phase is to have the program an integral part of the Waterloo culture, with sustaining funding from the University and Industry.

The objective of the WCDE group is to enrich student experience in an academic setting using more realistic problems, to allow students to more consistently see the complexity of real engineering, realize the interconnectedness of concepts and courses, and to develop analysis and problem solving skills, including judgment. Waterloo has a strong experiential learning culture, as evidenced by the co-op program. The underlying principle of WCDE is to strengthen and enrich this culture through learning from the experience of others. The mechanism used is the case study, moreover, case studies derived directly from our own students' experience. An important underlying principle is the strong parallel between the engineering method and the learning process; as a result, an effective documentation of an engineering design or analysis can naturally be applied to a learning experience. Core elements of the resulting case study include the background context (who and why) and a statement of the general problem (what); the technical context, approach and analysis (how); and the results, with appropriate verification and evaluation (is it correct, and what does it mean).

Waterloo engineering students are required to complete 3 work term reports to document engineering design and/or analysis during the course of their program. The work term reports are milestones that must be completed, but there is currently no life after submission unless the report is used directly by the company. Our students produce over 3000 work reports each year. This is an incredibly rich and diverse source for case studies. WCDE was created to develop a rigorous system to harvest, develop and release 30-45 cases per year, across the faculty.

Figure 1 illustrates the core elements of an effective case study or work term report: sufficient technical context, real data, and appropriate analysis and verification [6]. This illustrates the components of a case that was written for use in a first year introduction to mechanical engineering course. Students were asked to recommend a suitable heating unit for retrofitting a stone house, following a significant upgrade to the insulation levels, and to present the results in the form of a work term report. The learning objectives were to demonstrate the role of simple engineering calculations in engineering design while providing experience writing a technical report. Table 2 compares the structure of the work term report and the corresponding case study. The content is the same. The major difference is a slightly stronger emphasis on the context and background for the case study, and the different general format. The case itself is represented by the first component, and this is typically the only material released in full to the students. The subsequent modules are made available only to instructors.

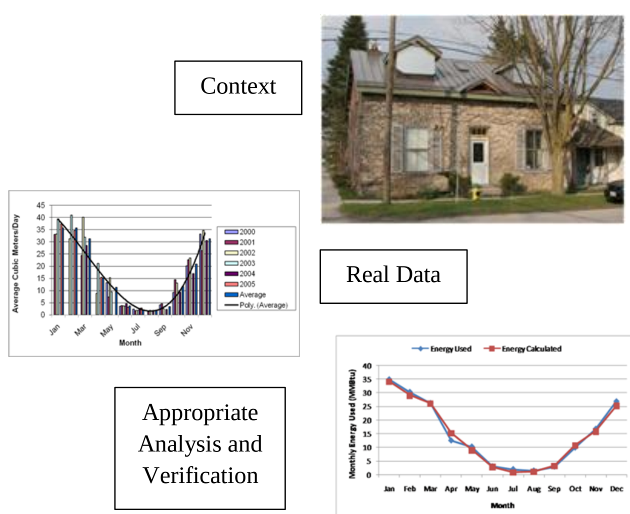

Figure 1: Core elements of a case study or work term report.

Table 2: Comparison of Work Term Report and Case Study Structures

Work Report	Case Study
1. Introduction 2. Background	**Case Study:** Introduction Background Context General Problem Statement
3. Thermal Model 3.1 Background Theory and Assumptions 3.2 Model Verification 3.3 Model Results for Renovated House	**Module 1 – Thermal Model** Background Theory Model Verification Model Results Heating Requirements
4. Selection of Heating System 4.1 Heating Systems Considered 4.2 Cost Comparisons 4.3 Selection of Best Option	**Module 2 – Design Solution** Options Considered Cost Comparisons Design Selection
5. Conclusions 6. Recommendations	**Module 3 – Teaching Note** Lessons Learned

The WCDE group is led by the NSERC Chair in Design Engineering (Steve Lambert), with 2 full time design engineers who develop cases and champion their implementation, and 1-2 co-op students each term to write cases. Ongoing operational and strategic advice is provided by an Industrial Advisory committee, with 5-6 industry representatives and several higher-level University representatives, including one from Cooperative Education and Career Services, and the associate Dean of Cooperative Education and Professional affairs within the Faculty of Engineering. A separate Design Champions Committee provides more tactical advice and serves as a direct link with each Department. There are instructor representatives from each Department in Engineering as well as representation from Cooperative Education and Career Services, and from the Centre for Teaching Excellence. These committees meet once each term, three times a year. During the start-up phase, these committees met separately. However, it has been found that a common meeting is more dynamic, and facilitates more wide-ranging discussion. To date, direct student input has been limited to co-op students working for WCDE. Recently we were approached by students who had experienced a case implemented in their class, and wanted to contribute. This has resulted in the formation of a student group, with representation to be solicited from each Department; these students will be asked to participate in all subsequent term meetings.

Case Development

The rigorous case development process, Figure 2, starts with submission of work term reports (or design reports; case source). This relies on student submission of reports to comply with Waterloo's strong culture of respecting intellectual property: "Everything you Discover at Waterloo Belongs to You". Grassroots promotion and harvesting has gradually been supplanted by recommendations from report markers. Markers are given guidance on what makes a good case study, and asked to recommend 5-10 reports per Program each term. The criteria include general report quality (completeness and strong analytical content, including a rigorous approach and appropriate verification), and relevance for the curriculum. This system was phased in Department by Department, with marker recommendation sheets first; these sheets explain our program and that the student's report was recommended for submission to WCDE for possible conversion to a case. Many Departments have now moved on to a more concise process, by changing the actual marking form to include a checkbox recommending submission to WCDE. Students are then reminded to submit the recommended reports for potential conversion. This strategy was based on gradually building awareness and support, with an eye to integrating the case recommendation process into the academic culture.

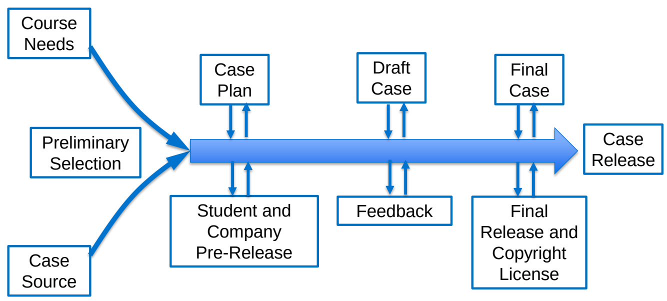

Figure 2: WCDE Case Development Process

Submitted reports are selected for conversion based on a combination of quality and priorities (course needs) as identified by faculty members. The Design Champions act as the liaison between WCDE and the Departments to identify target courses, professors and concepts. Students who submit reports are asked to confirm their interest in participating and to provide contact information for their industry supervisor. The supervisor is contacted and provided with general information about the program and if receptive is sent a case plan for approval. The case plan outlines the case structure, contents and timeline for development. A copy of the final release form and copyright agreement are included with the case plan for preapproval by the company legal department as required. There is sometimes a question about who at the company can approve final release; having all the necessary information at the beginning helps to minimize delays in the release process. The company and the student have an opportunity to comment on the material to be released and are asked for more material as necessary at the start of process to minimize delays and unnecessary effort on both parts.

Case conversion focuses on the structure, supplementing available material in the report for completeness and to add multimedia components, and technical editing for clarity. The case itself provides the context and a general problem statement. The balance of the report is presented in logically structured modules to present what was done to solve the problem. These modules are typically never released to students, but made available to instructors to provide guidance and a source of additional data as required. This modular structure maximizes case-use flexibility. Separate presentations and assignments are created for each implementation, and these are stored in the database for subsequent reference and potential reuse. Conversion of the case is carried out by WCDE staff, who typically become co-authors, with the student, on the case and the modules. Each case is reviewed internally for general quality, including by a part-time technical editor. The student and industry partner must approve the final version before it is released for use, and a copyright license form is signed by all authors.

The case structure follows the engineering method as a general guide for pedagogy. The underlying philosophy is that the engineering design process is consistent with the experiential learning process [7]. Each can be interpreted loosely as a series of sequential stages wherein a better understanding of the problem and solution are simultaneously constructed. Each stage involves an iterative process of exploration and evaluation, of successive divergent and convergent thought processes.

Case Implementation

The modular case structure chosen, and the large quantity and diversity of cases that has been and continues to be developed, means that there are now rich opportunities for implementation. The most frequent application envisioned would be illustrative examples and assignments [8]. These would allow instructors to frame course topics in the context of current industry practice and motivate students to focus on the core engineering analyses. This gives students an opportunity to learn to deal with this critical early stage of design and analysis in context; this context is typically lacking in text-book problems, which by definition focus on the core engineering science, stripped of extraneous (real-world) detail. Cases can also be used following the presentation of a topic to help students to apply and integrate their knowledge and understanding. Having first gained a preliminary understanding of a concept, students are perhaps in a better position to discuss the appropriateness and limitations of an analysis, and its applicability to a given real situation. On the other hand, cases can also be used as the basis for problem-based learning, wherein students are presented with the case first, and then asked to identify what is necessary to solve the problem, and formulate a plan to accomplish this.

This pervasive use of case examples and assignments is meant to form a foundational bridge between engineering practice and academic study. It provides students with the opportunity to learn to set up and frame engineering problems, gives students practice making appropriate simplifying assumptions, and encourages the development of their engineering judgement. This also represents a relatively easy transition for instructors new to case use, and provides an opportunity to introduce more group work so that students gain more experience working in teams. This foundation will better prepare students to tackle more intensive case use, such as case analysis and/or design projects, which typically take longer, from a few weeks to the entire term.

Case analysis projects are a natural extension of case assignments, but more complex and intensive. The focus remains on engineering analysis and on making appropriate assumptions to establish the appropriate level of effort and the methods of verification. Case design projects are more open-ended, have more opportunity for creativity, and more design decisions are required. They can be used to encourage innovation and hone judgement skills.

Waterloo operates under a cohort system, so students have a common set of courses each term and in subsequent terms, with the exception of a few elective courses concentrated in the final years. As a result, a particular case can be used in more than one course, either in the same term to help integrate topics across courses, or in sequential terms to illustrate successive levels of refinement in engineering analysis, or different technical and non-technical aspects of the case. Instructors need access to the history of case use so that they may effectively draw ties to students' earlier exposure to the case.

3. DISCUSSION

This is certainly not the first use of cases in engineering. There has been considerable experience using cases in a specific courses: first year introductory courses [9], or design courses [10, 11], for example. Petroski [12] has long advocated the use of case histories of engineering failures to teach engineering design. Our program tends to be unique in its attempted scope, across the entire curriculum. This is only possible with a reliable and sustainable source of relevant cases.

Case use is more prevalent in law and business, and WCDE has taken advantage of this experience to study the case development and teaching process; all WCDE full-time staff have attended case writing and teaching workshops at the Ivey School of Business [13]. These have been very instructive; we have adapted many of their processes to our own efforts, especially the case development and release process [14]. But there remain differences between business and engineering cases [15]: our engineering cases almost always include a solution, although that is typically not released to students, except informally by the instructor after discussion of the case to provide some 'closure'. And few of our cases are so-called decision cases; they focus more on a process, especially design and analysis, than business cases. Several of us have also attended workshops on Cases in Science and Engineering, hosted by the National Centre for Case Study Teaching in Science [16]. Again, their approach has been instructive, although they tend to be less formal [17], with a focus on the story and narrative, than the engineering reports which form the basis for our cases. Although there is merit to this less formal approach, our intuition and limited polling of our students suggests that they prefer a more formal approach – they tend to take the case more seriously when it is expressed in a formal report format.

This is an ambitious project to change the culture of teaching at Waterloo to effectively integrate engineering practice into the undergraduate curriculum using case studies. A conservative implementation approach was taken, first focusing on case development with gradually increasing implementation, both in terms of quantity and intensity. The strategy was to focus initially on cases which could be used throughout the faculty, across disciplines, in first year. Case writing experience was obtained writing cases from our own experience and in direct collaboration with industry and others, before students were asked to submit their work term reports for conversion. For example, a rainwater harvesting case was developed in collaboration with Engineers Without Borders (EWB; www.ewb.ca), and used in first year introduction to engineering courses across the Faculty to introduce students to the engineering design process [18]. Due to the large number of students involved, this allowed us to explore online implementation methods. Student response was positive. In-class discussions were helpful to increase engagement; some of these discussions were led by student members of the local EWB Chapter.

Early cases were developed from our own experience and through direct collaboration with industry. These cases were the most comprehensive, and the easiest to tailor to a specific learning outcome. Cases developed directly with industry were more time consuming to develop since the case writer had to learn specifics about the context from interviews and detailed reports, and relied on significant assistance from industry representatives. The case-writing process followed the guidance for business cases [14]. The format followed that outlined above: the case itself described the general context and the specific challenge, in sufficient detail that students could formulate a solution plan. Detailed data and analysis results were placed in separate modules for the use of the instructor.

By comparison, development of cases from work term reports is more efficient, but there is more limitation on the learning outcomes of the case. One is constrained by the material provided in the original report, with the exception of limited additional material made available during the case writing process. This puts more importance on the selection of source material. Fortunately, we have been successful at having a large quantity of reasonable work term reports submitted. Typically, we get from 50-100 reports each term, from which we would select about 10 to be converted to case studies. More recently, we have focused more on getting recommendations from work report markers. During this transition, the number of submitted reports has gone down somewhat, but the quality and suitability has gone up. The intention is to get 5-10 recommended reports each term, from each Program, providing a sustainable supply of good quality case material. The conversion rate is about 1 case per month per staff member, including WCDE co-op students. Efforts are made continuously to improve this conversion efficiency, in terms of both quantity and quality. These include the development and sharing of best practices within our group, as well as the preparation of a co-op student manual for the writing of cases.

A pilot study is currently underway to investigate the benefits of having students write cases directly, in lieu of work term reports. We are working with a partner company and 2 Departments to ask some students to voluntarily write cases. The results are being evaluated to ensure that the academic objectives of the work term report are still being met and to look for additional benefits to student learning. It is hypothesized that students will be more motivated to write a case than a work term report, and will learn more from their experience since there is a more direct focus on learning. It is also hoped that, if the pilot is implemented more extensively across the faculty, this will improve the quality and suitability of cases that are submitted to our group, while minimizing the effort required for editing.

The implementation strategy continued with a focus on design courses in our home Department: Mechanical and Mechatronics Engineering. Cases were developed in direct collaboration with industry and through conversion of student design project reports. These design project reports are a natural complement to work term reports, with the former covering a wider range of the design process, with less detail at each level. Work term reports typically are more narrowly focused, but have a deeper level of analysis. These design reports were effectively used to illustrate the design process in design project courses [19], and were even used as midterm exams to verify student understanding of the design process.

Student response has been quite positive, with an appreciation of the real-world nature of cases. In a first year Electrical and Computer Engineering course, students were walked through the design of an electrical storage system for a hybrid electric fuel cell vehicle [20] – our University's entry into the EcoCAR challenge. They saw this as an engaging introduction to the design process, and some liked the way it showed how electrical and mechanical engineers worked together. At the same time, others thought that the case was not focused enough on computer engineering, their discipline, and failed to see the usefulness of looking at a broader picture. This identified the tendency in many of our students to want to focus narrowly, and hopefully will also provide a mechanism to broaden their perspective. In a final year mechanical design course, a case was used to illustrate brake design in a real-world application [21]. Again, students were appreciative of the way this case tied together theory and practice, although some were frustrated with the difficulty of obtaining a solution. Industry members of the industrial advisory panel were gratified by both the positive and negative feedback on the use of these cases. The negative feedback illustrated that we were challenging the students' pre-conceptions of the simplicity of engineering problems, and their desire for a single right answer.

Current implementation emphasis is on broadening case use throughout the faculty, and in a wider range of engineering science courses. There is now more focus on cases developed through work term reports, and we are currently 5-10 new case implementations each term. A new implementation involves any combination of a new case, a new professor, or a new course. To get things started, we offer to present the case for an instructor, so that they can implement it or another case in subsequent terms. We are also developing a case teaching workshop, to be offered each term to interested instructors: graduate student teaching assistants and faculty members.

We now have a critical mass of cases (> 60) and are on track to produce a further 30-45 cases per year. Implementation has naturally lagged the production of cases, but is ramping up. It is becoming more and more necessary to have a formal method to track both case development and implementation. Focus has therefore been placed on the development and implementation of an online database system so that instructors can search our database of cases and request review copies. This database will also track case implementation so that instructors can access a history of case use, to see what cases their current cohort has seen and how they have been used. At the same time, more work is required to investigate and clarify best practices for case implementation, and to offer training and support to faculty members. This will be done in the context of the scholarship of teaching, with more rigorous study of the benefits and issues with case use. Emphasis will gradually be placed on more intensive and effective ways to use cases, case projects for example, to increase student peer learning and teamwork skills.

4. CONCLUSIONS AND FUTURE WORK

This has been an incredible learning experience, started with the germ of an idea to leverage work term experience, to develop the overall strategy and management practices to develop a case development and implementation program. We continue to learn about case development and use. A critical mass of cases has been developed and the rate of case production has reached the target of at least 30 new cases per year. Cases have been implemented in a wide range of courses, from first year to graduate level, across all Departments in the Faculty. Efforts are currently focused on expanding case use, especially outside of mechanical engineering, and on improving the impact of case use, through peer learning and class discussions. Cultural change has started, but more work is necessary.

There has been some interest in expanding this program outside of engineering at Waterloo, and outside the University. Care must be taken when making these cases available outside Waterloo, to respect student copyright and the wishes of industry partners. Currently, industry partners are given the option of restricting case use to Waterloo only. Almost all have chosen this option. It is not clear why this is so, but further investigation and discussion is required to change this. Another consideration is whether to charge for cases, as is done for most business cases. This provides some measure of control to ensure these cases are used effectively and that modules are not made public, and a way to recoup some administrative costs. No decision has yet been made on whether to pursue this business model, or an open-source model.

5. REFERENCES

[1] Engineers Canada, Canadian Engineering Accreditation Board (CEAB), online, accessed February 2012, http://www.engineerscanada.ca/e/pr_accreditation.cfm.

[2] Engineers Canada, Canadian Engineering Accreditation Board (CEAB), online, accessed February 22, 2012, http://www.engineerscanada.ca/e/files/Accreditation_Criteria_Procedures_2010.pdf.

[3] Canadian Engineering Education Association (CEEA), online, accessed February 20, 2012, http://www.ceea.ca/index.php.

[4] Natural Sciences and Engineering Research Council (NSERC), Chairs in Design Engineering, online, accessed February 20, 2012, http://www.nserc-crsng.gc.ca/Professors-Professeurs/CFS-PCP/CDE-CGC_eng.asp.

[5] WatPD Engineering, "Professional Development for the Engineering Workplace", online, accessed February 20, 2012, http://www.engineering.uwaterloo.ca/watpd-engineering/.

[6] S.B. Lambert, C. Campbell, and O. Nespoli, "Leveraging Student Co-op Design Experience Using Case Studies", *International Conference on Engineering and Product Design Education*, Universitat de Catalunya, Barcelona, Spain, 4-5 September, 2008, 6 pages.

[7] D.A. Kolb, "Experiential Learning: Experience as the source of learning and development", *Prentice-Hall, Inc.*, Englewood Cliffs, NJ, 1984.

[8] T. G. Gill, "Informing with the Case Method: a guide to case method research", *Informing Science Press*, 2011.

[9] J. N. Jensen, "A Case Study Approach to Freshmen Engineering Courses", *Proceedings of the 2003 American Society of Engineering Annual Conference & Exposition*, Nashville, Tennessee, June 22-25, 2003.

[10] P.K. Raju, C. S. Sankar, Gerald Halpin, and Glennelle Halpin, "An Innovative Teaching Method to Improve Engineering Design Education", *Proceedings of the 2000 American Society of Engineering Annual Conference & Exposition*, St. Louis, Missouri, June 18-21, 2000.

[11] L.G. Richards and M. Gorman, "Using Case Studies to Teach Engineering Design and Ethics", *Proceedings of the 2004 American Society of Engineering Annual Conference & Exposition*, Salt Lake City, Utah, June 20-23, 2004.

[12] H. Petroski, "To Engineer is Human: The Role of Failure in Successful Design", *Vintage Books*, 1992.

[13] Richard Ivey School of Business, "Ivey Case Method Workshops", online, accessed February 20, 2012, http://www.ivey.uwo.ca/workshops/ivey_workshops.html.

[14] M. R. Leenders, L. A. Mauffette-Leenders, and J. Erskine, "Writing Cases", Fourth Edition, Richard Ivey School of Business, The University of Western Ontario, 2001.

[15] O. Nespoli, A. Hagedorn, C. Campbell, and S. Lambert, "A Comparison of Business Case and Engineering Design Case Structures", Canadian Design Engineering Network Conference, CDEN 2008, July 27-29, 2008, Halifax.

[16] National Center for Case Study Teaching in Science, 2012, online, accessed February 2012, http://sciencecases.lib.buffalo.edu/cs/training/workshops/.

[17] C. F. Herreid, editor, "Start with a Story: The Case Method of Teaching College Science", *NSTA Press*, 2006.

[18] C. Campbell and S.B. Lambert, "Using Case Studies to Teach Introductory Design Concepts to First Year Engineers", *Proceedings of the 2007 American Society of Engineering Education Annual Conference & Exhibition*, Honolulu, Hawaii, June 24-27, 2007.

[19] W. Melek, G. Stubley, O. Nespoli, and S.B. Lambert, "Use of Case Studies in Teaching Design Workshops for Engineering Students", *CEEA/ACEG 2010 Inaugural Conference, Canadian Engineering Education Association*, Kingston, Ontario, 7-9 June, 2010.

[20] S.B. Lambert and D. Effa, "Leveraging Design Experience Throughout the Curriculum using Case Studies", abstract accepted for presentation, *14th International Conference on Engineering & Product Design Education*, Antwerp, Belgium, 6-7 September, 2012.

[21] O. Nespoli, H. Tempelman, R. Spencer, and S.B. Lambert, "Disk Brake Design Case Study Implementation Method and Student Survey Results", *Proceedings of the 2011 American Society of Engineering Education Annual Conference & Exposition*, Vancouver, British Columbia, 26-29 June, 2011.