# LEVERAGING STUDENT CO-OP DESIGN EXPERIENCE USING CASE STUDIES

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**ABSTRACT**
All engineering students at Waterloo participate in the co-op program, wherein they gain work experience whilst completing their degrees. A requirement of the program is that students complete a set of 4 work term reports to document this experience. These work term reports represents a diverse source of engineering experience which has not been tapped in any consistent way.
A group has been set up at the University of Waterloo to investigate the development of engineering design case studies from students' work term reports. In its most general form, a design case study represents a real situation and real data, from which students can learn to apply engineering science and design principles. They can be used to provide context for material covered in courses throughout the curriculum, to integrate material covered in several courses, and to illustrate the multidisciplinary nature of most real problems. Realistic case studies can be very motivating, particularly if they have been derived from the experience of their colleagues.
The long-term goal of the group is to provide students with the option of submitting engineering design case studies in lieu of work term reports. Work to date has focused on the development and use of example case studies. The structure of engineering design cases is presented and contrasted with current work report requirements. Experience gained to date is discussed, along with quality control, case distribution, and intellectual property issues.

*Keywords: Design case studies, co-op education*

## 1 INTRODUCTION

There has been increasing interest in improving the design skills of engineering students [1]. The University of Waterloo has tried hard to balance engineering science and practice, including design, since its inception in 1957. All engineering students must participate in the co-op program, wherein they alternate 4-month academic terms with work terms in industry. This has been very successful, attracting very strong students and providing them with invaluable hands-on professional skills in engineering practice, including communication, project management, and design. While each student gains invaluable experience during their work term placements, there remains significant potential for improvement if a mechanism were put into place to leverage this individual experience for the benefit of others. Case studies provide an ideal mechanism for such transfer if the cases are derived directly from student work term experience.
The NSERC – General Motors of Canada Chair in Collaborative Design has been set up in the Faculty of Engineering at the University of Waterloo to create a program to develop and implement design case studies based on student work term experience. This

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## 2 DESIGN CASE STUDIES FROM CO-OP STUDENT WORK TERM REPORTS

All engineering students at the University of Waterloo alternate co-op work terms with academic terms. An engineering work term must be technical in nature and involve 'engineering', and at least 4 of these 6 work terms must be documented in the form of a work term report. Waterloo has one of the largest engineering faculties in Canada and currently places approximately 2000 engineering students across all disciplines on work term every 4 months, resulting in about 4000 engineering work term reports each year. This represents an immeasurable wealth of experience which could be used to enrich the academic experience of all engineering students.

### 2.1 Co-op Work Term Reports

The work term report must be related to a student's work term experience and have 'analytical content', which typically involves the application of engineering science to the analysis of a specific situation, or the design of component or system. A typical work term report is 15-20 pages in length. The expectation is that the work term reports will help to integrate academic and industrial experience for the student, but emphasis is on providing experience to improve the quality of written communication. There is renewed interest in emphasizing this integration role through the practice of critical reflection [2].

Work term reports are accepted in a variety of formats. Figure 1 is an example work term report outline. This outline was provided to first year students in a first year concepts course for mechanical engineers in the fall of 2005. A key objective for this course was to introduce students to the profession and prepare them for their first work term placement, especially the writing of a work term report. Students used the design process and engineering analysis to recommend a heating system for Professor Lambert's house.

1. Introduction
2. Background (Context)
3. Thermal Model
   - 3.1. Background Theory and Assumptions
   - 3.2. Model Verification
   - 3.3. Model Results for Renovated House
4. Selection of Heating System

*Figure 1 Report outline for the Elora home heating project; house shown on right*

### 2.2 Design Case Studies

Cases are a “story with an educational purpose”, and have been used in the study of law, business, medicine, and science and engineering [3, 4]. Cases provide context for the discussion of information and concepts related to a course, and may form the basis of problems to be discussed in class and/or completed as assignments or projects, either individually or in groups. Cases are typically open-ended with more than one reasonable solution. Students who use cases gain an appreciation for complexity, different perspectives, and the application of material covered earlier in the curriculum. While some schools use cases as the primary mode of teaching, most will use cases as part of a mixture of methods.

Cases represent a simulation of reality, and will always be a crude approximation to the real physical and social context. To engage and motivate students, the case must allow the student to put themselves into the situation, as an active participant. This is made easier as the authenticity and relevance of the case increases. Authentic cases are based on real data and real situations. The most authentic cases are written by an actual participant in a real situation, or by a third party based on interviewing the participants. Cases written by co-op students based on their own experience are inherently authentic, but care must be exercised to ensure that the data, approach and analyses are correct. This must be addressed as part of the release process by requiring that the employer sign off on the use of the case, and that the technical analyses be presented clearly enough to be readily verified by a third person.

Many cases are narrative in nature, making it easier for students to imagine themselves participating. Some emphasize the narrative style through the use of actual dialog between characters. Most engineers are not comfortable with such an informal style; students are trained to write in third person. Dialogue can be considered corny or as a transparent artifice to engage the student, particularly if poorly written. This represents a particular challenge when trying to write cases based on work term reports, which are in a formal style.

Engineers, both professors and students, have a natural tendency to focus on quantifiable technical aspects. This was observed in a case to design a rainwater harvesting system for a village in India, developed in collaboration with Engineers Without Borders (www.ewb.ca). The case was used in first year concepts courses throughout Engineering at Waterloo [5] to illustrate the design process and the effective use of engineering simulations using Excel. The social context was emphasized by inviting a member of the local EWB chapter, with actual overseas experience, to discuss the importance of social context.

Many business cases do not have solutions available; it is recognized that the important feature of the case is the process of getting to and justifying a solution. The actual solution is not critical. For engineering design cases, solutions will typically involve detailed engineering analyses or simulations with varying degrees of verification. Having these available to the professor makes it much easier to adopt a case for instruction. This also provides more flexibility in the use of the case. The provided solution can be discussed in class and compared with students results; it can be used as the basis for discussion of alternate solutions; it can be used as an example of a particular solution method; or provide students with context for the discussion of specific engineering concepts.

### 2.3 Example Design Case

A case based on the work report outlined in Figure 1 consists of a description of the situation and contextual background necessary to understand the situation. This case is based on a real situation. Professor Lambert had recently purchased a 140-year-old stone house which had no significant insulation. He had committed to gutting the interior to upgrade the insulation and to use hydronic radiant in-floor heating throughout the house. Specifications for the existing forced-air natural gas furnace, and data from natural gas bills for the prior 5 years of use were supplied. Figure 2 is taken from the case and illustrates the seasonal natural gas usage. The case ended with a general problem statement outlining the need to heat water for the radiant in-floor heating system once the house was insulated. The actual case consists of 3 pages of text and figures describing the situation, and a further 3 pages of appendices. Appendix A of the case provides the rough dimensions for windows, doors, walls and ceilings. Appendix B of the case provides the natural gas used, cost, and degree days for most months, summarized from the actual heating bills.

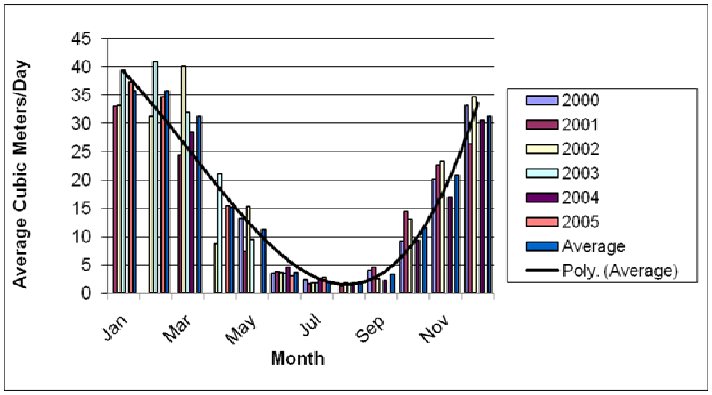


*Figure 2 Summary of actual monthly natural gas used based on available heating bills*

This case, corresponding to the work report outlined in Figure 1, consists of several modules. The case itself is module 1 and contains the material from the introduction and background sections of the work report. A separate module presents the thermal model, section 3 of the work report, including the background theory, model development and verification. A final module presents the design selection, justification and results. This modular approach is necessary for the case to provide maximum flexibility in use. In some classes, students would just be given the case, and asked to work through a solution. In other classes, the various solution modules would be given to the students as background and/or as the basis for classroom discussion.

This case was used in the first year Mechanical Engineering course over a period of three years. In the Fall 2005 class, students were given just the problem statement and worked on the thermal model and design selection throughout the term, culminating in a work term report as outlined in Figure 1. In the subsequent year, students were given the case and background module on the thermal model, and asked to investigate an active solar thermal option. They too were asked to submit a work term report summarizing their results. In the third year, students used modules outlining the thermal and solar models as background, and designed a seasonal energy storage system. The final deliverable was again a work term report documenting their solution.

This case structure has evolved to strengthen the relationship between the case study and a work term report. The case itself emphasizes the problem definition of a work term report, and separate modules contain the analysis or design which is a required element of all work term reports. Keeping them separate maximizes flexibility. The similarity minimizes the work required to convert a work term report to a case, which is largely editorial.

## 3 DISCUSSION

The experience using this case demonstrated the benefits of working with a real situation in the teaching of engineering science concepts and design in first year. Students in first year were receptive to working with a real situation, particularly the more mature students, who immediately saw the benefits of working with real problems, and understood the need for judgment and that there was no single right answer. However, even younger students asked the professor in subsequent terms about progress and which solution had been implemented.

The particular case discussed illustrates the relationship between a work term report and a case study, and demonstrates the feasibility of generating case studies from work term reports. Its use in three successive terms also provided experience with reusing a case; here each successive class built on the earlier results. The case itself was unchanged. Separate modules containing technical background and excel analyses were made available to each group of students as appropriate, but the final solutions and recommendations were not released.

This experience suggests that a modular and flexible structure is required for design cases. This structure is completely compatible with the present work term report requirements, and it should ultimately be possible to allow students to submit design case studies instead of work term reports. An additional module which relates the content of the case study to the work term experience, including lessons learned and the technical and professional concepts addressed, would address the need for active reflection to maximize student learning from the work term experience [2]. The Department of Electrical and Computer Engineering currently requires students to complete such a section for existing work term reports. This reflection module could also form the basis for case teaching notes, and keywords drawn from this can be used to help professors identify suitable cases to consider for specific courses. This represents a true win-win situation for the student generating the case and professors and subsequent students using the case in class.

To date, focus has been on writing cases, either directly or converting them from work term reports. Converting work term reports is more efficient, since this requires only editing and formatting changes. A major effort is required to promote the program to students so that they will volunteer their work term reports. We have given talks to individual classes and made permission forms available when work reports are submitted or returned to students. In addition, we have talked directly to students working with partner companies. Design Chair staff explain the program and make suggestions on possible work report topics. This offers benefits to all concerned: industry gets to promote themselves through their students work term reports, students get report topic suggestions early in the term, and the Design Chair group gets access to ‘pre-approved’ work reports. Various other promotional and incentive programs are currently under consideration.

These early attempts have already been successful, and emphasis is now shifting to filtering these reports to establish priorities for conversion to cases, based on quality and

fit with anticipated course needs. These needs are identified by the design champions group, a representative from the faculty of each of the engineering Departments. Once a work report has been selected, the student is asked to provide contact information for their co-op supervisor, so that they may be informed of the program and asked to give permission for the work report to be converted to a case study. They can express any reservations at this point, before any effort has been expended in reformatting and editing the case. The industry contact and student must of course approve the final case before it is released for use in class. This is important to ensure that the case accurately reflects the real situation and positively portrays both the student and company.

The next step in the process is to explore the issues and advantages of having students submit case studies directly, in lieu of work term reports. A pilot study has recently been proposed. To date, administrative and academic approval procedures have been investigated, and industrial supporters of the Design Chair program have been contacted for potential participation in the pilot.

## 4 CONCLUSION

The results presented demonstrate the feasibility of generating cases from work term reports. This is based on the strong correspondence between the content of the case study and the work term report, and the potential motivational and pedagogical advantages of using cases derived from actual student co-op experience. Little active promotion of this program has occurred to date. However, students have already volunteered existing work term reports for consideration as cases, professors have already provided lists of concepts for which they would like industrial-based cases, and industry partners have already agreed to encourage their work term students to submit case studies to address these needs. A strong start has been made to the pervasive use of case studies to further integrate and strengthen the co-op program at Waterloo.

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