INTRODUCTION OF AN ACTIVE LEARNING COMPONENT THROUGH RESEARCH REPORTS IN A LABORATORY COURSE

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Abstract – *Mechanical Engineering Laboratories is a third-year course at the University of Manitoba that covers the application of mechanical engineering principles to relevant experimental problems. The course spans two terms, counts for two credit hours per term and traditionally required student teams to prepare formal laboratory reports only.*

An active learning component was introduced by assigning students to write research reports on topics that would otherwise have been covered in the lectures. This allowed us to enable additional laboratory groups during former lecture slots and accommodate the program's enrollment increase from 80 to 120 students. Introducing research reports also allowed students to learn independently, research beyond the level of detail in the course if they wished, and practice their lifelong learning skills along with teamwork skills.

Most students did well in this component of the course. Student feedback comments on the research reports were mostly positive. This experience suggests that an active learning component through research reports in lieu of some lectures may be a useful active learning tool in an upper-level laboratory course.

Keywords: Active learning, research reports, laboratory course.

1. INTRODUCTION

Mechanical Engineering Laboratories (MECH 3980) is a core mechanical engineering undergraduate course at the University of Manitoba. This course emphasizes the application of mechanical engineering principles to selected laboratory problems. It spans the fall and winter terms of the academic year. Each term counts for two credit hours.

The fall term consists of three successive experiments in solid mechanics and vibrations. The first experiment uses strain gages to measure the stress distribution on a loaded bicycle frame. The second experiment uses photoelasticity to measure the stress distribution on a cantilever beam and a perforated buckled plate. The third

experiment uses a balancer to measure and correct the dynamic unbalance of a rotating shaft.

The winter term consists of four successive experiments in thermofluids. The first experiment studies an air conditioner unit and measures its effects on the temperature and humidity of air in a duct. The second experiment studies the heat transfer between a heating element and its surroundings by radiation and free convection. The third experiment studies the heat transfer across a concentric-tube heat exchanger operating in parallel and counter flow. The fourth experiment studies pressure head losses on an duct and the efficiency of an axial fan for varying air flow rate.

Traditionally, students attend laboratories along with corresponding lectures. The lectures cover the theoretical background required to understand the experiments and analyze the data collected. Lectures also cover how the sensors (e.g. strain gages and thermocouples) used in the experiments work. There are three scheduled hours of lecture per week.

The experiments run in succession where a typical experiment accommodates five students and takes one hour to run. Each laboratory session lasts three hours. There are three of these laboratory sessions per week. Each laboratory experiment runs for two weeks and this sets the capacity of the course at 90 students.

An increase in cohort size in the fall 2009 term due to a strategic increase in the mechanical engineering program's enrollment motivated the course instructor to consider how to incorporate more students to the course. Increasing laboratory hours was difficult due to scheduling conflicts with other courses. The instructor decided to use lecture hours to run laboratories during the two weeks when each laboratory was active. This provided additional laboratory space for 30 students whereby the course could now accommodate 120 students. This represents an increase of a third; however, the number of scheduled lecture slots was reduced to six weeks of lecture instead of twelve. This posed the question of how to cover the content of the lectures lost. The answer was the introduction of research reports.

2. METHODOLOGY

Students were assigned to write short research reports on topics related to the sensors used in the laboratory experiments. Some of these reports also asked students to research some of the basic theory behind the experiments (e.g. psychrometry, concentric-tube heat exchangers) and this theory would also be reviewed and supplemented in the lectures as necessary. Due dates were timed so students would submit the research reports prior to working on their corresponding laboratory reports.

Students submitted seven research report and seven laboratory reports through the one-year course. Research reports were worth 20% of the mark of the course, and formal laboratory reports were worth the remaining 80%. Depending on the length of the assignment, research reports were done individually or in groups of 2-3 students and were typically 4-8 pages long.

Two sample research report assignments appear in Appendix A. The first sample is taken from the initial introduction in the fall 2009 term. This research report accompanies a laboratory in mechanics of materials which involved the evaluation of beams in bending using displacement transducers, strain gages and load cells. The approach was very much open ended with a practical aspect used to encourage and engage the students with the assignment.

The second sample corresponds to the second thermofluids experiment for the winter 2015 term. This experiment studies the radiation and free convection heat transfer between a horizontal cylinder (heating element) and its surroundings. The first part of this research report establishes the basic concepts of radiation and convection. It also reviews the basic theory behind free convection for a horizontal cylinder. The second part covers the sensors used in this experiment to measure temperature (thermocouples) and how they work. The third part takes the student further from this experiment and asks about temperature sensors different from those used in this laboratory. This assignment is more structured than the fall 2009 assignment previously shown. The reasons behind this change are discussed in the following section.

3. RESULTS

In addition to releasing lecture hours to run laboratories instead, research reports introduced an active learning component to the course. Having students research and learn certain concepts on their own helped them practice their lifelong learning skills and, for reports done in groups, their teamwork skills. If they wished, students also had the opportunity to learn about sensors in a level of detail beyond the scope of the course.

Students rarely missed writing a research report. Most students did well in this component of the course. Most student comments received in the course evaluations

regarding the research reports were positive. Several students indicated they learned from the research reports, and preferred them over more frequent lectures.

Some critical student comments regarding the research reports appeared during the first two years when research reports were introduced. Two students felt that the credit load of the course should be increased following the introduction of research reports. This is probably because these students felt the expectations of the course had changed relative to the previous cohort. Similar comments did not appear in subsequent terms. This is probably because students felt the expectations of the course were the same as for their previous cohort.

Research reports evolved to be longer and more structured over time. Most thermofluids research reports also included questions related to the theoretical background behind the experiments. Some of these changes appeared in response to student feedback over the years.

First, students requested more detailed rubrics to help them better understand the expectations and marking scheme of the research and laboratory reports. This led to more structured rubrics that clarified the allocation of marks for different tasks of the report. Students also noted their preference to work on research reports with the same team they had for their laboratory reports. This led to longer research report assignments to accommodate student teams of typically three members.

Second, students indicated they had difficulties with some heat transfer reports because they had not completed the heat transfer course before doing these laboratories. The instructor also noticed students had challenges with psychrometric concepts from a pre-requisite course. Although these topics were reviewed in MECH 3980 lectures, the instructor felt that having students also research or review these topics on the research reports was a valuable learning tool.

Despite adding some theoretical background concepts to the assignments, research reports remained focused on the basic principles behind how sensors used in the laboratory worked.

All student feedback comments that mentioned research reports between fall 2009 and winter 2016 appear in appendix B.

4. CONCLUSIONS

Substituting some traditional lectures with research report assignments proved successful for a third-year laboratory course. Research reports increased laboratory hours and introduced an active learning element to the course. They also allowed students to exercise their lifelong learning skills and, for reports done in groups, their teamwork skills.

Once research reports became norm, the majority of student comments about them was positive. Students felt

they learned from this exercise and welcomed the change from traditional lectures. This experience suggests that introducing research reports in lieu of some lectures is an effective supplement/alternative for formal lectures in an upper-level laboratory course.

APPENDIX A: SAMPLE RESEARCH REPORT ASSIGNMENTS

This appendix presents two research reports assignments. The first one is for the solid mechanics part of the course (fall term) and was written when research reports were first introduced in the fall 2009 term. The second one is for the thermofluids part of the course (winter term) and was written after a few years of using research reports in the winter 2015 term.

A.1 Sample 1

The following report was assigned for the fall 2009 term. This research report accompanies a laboratory in mechanics of materials which involved the evaluation of stresses, strains, and deflections of steel and aluminum beams in bending. The experimental equipment involved the use of dial gages, strain gages and load cells. This research report is meant to be done individually and has a suggested length of 4 pages.

A.1.1 Research report 1: load cells

You have been asked by your design team manager to purchase a suitable load cell for an upcoming set of experiments that you need to perform. The load range is 0 to 200 kg in compression with an accuracy of better than 10 grams. Since your manager knows little about load cells, prepare a short report describing the operation of at least three different commercially available load cell designs and source a suitable load cell for the given load range and accuracy. Also include a list of additional specification for the chosen load cell including input and output requirements.

A.2 Sample 2

The following report was assigned for the winter 2015 term. This research report accompanies a laboratory in free convection and radiation. It is meant for groups of 2 or 3 students and has a suggested length of 8 pages. The technical content is worth 32 out of 40 marks; the remaining 8 marks are allotted to technical writing competency (grammar, syntax and citations).

A.2.2 Research report 5: radiation, free convection and temperature measurements

Radiation and convection (10 marks)

- Define radiation, free convection and forced convection. Provide relevant equations. Explain the difference between these mechanisms.
- Consider a heated cylinder exposed to air. Explain how we could determine the convective heat transfer coefficient experimentally for free convection and forced convection (crossflow configuration).

Thermocouples (10 marks)

- Explain how a thermocouple works. Provide an equation for the output voltage of a thermocouple as a function of temperature. Show an example of a thermocouple table. Your explanation should include the need to have a reference temperature for one of the thermocouple junctions. Explain how to account for the reference junction not being at 0° C. What is the effect of choosing different material pairs in a thermocouple? (e.g. copper-constantan or iron-constantan.)

Temperature measurements (12 marks)

- Explain how we can measure temperature using mechanical means (e.g. ideal gas thermometer, liquid thermometer, bimetallic strip).
- Explain how we can measure temperature using electrical effects other than thermocouples (e.g. electrical resistance thermometer, thermistor).
- Explain how we can measure temperature using optical means (e.g. optical pyrometer.)

APPENDIX B: STUDENT FEEDBACK

All student feedback comments that mentioned research reports between fall 2009 and winter 2016 appear below. Comments appear in chronological order. The majority are positive. Notice that comments mentioning the higher workload introduced by research reports appear only for initial terms.

- "Research reports were a good learning experience but often too much work for the 2 credit hour course."
- "The research reports were a good idea to help us get some experience and knowledge, but lots of work, but helped distribute marks."
- "The introduction of research reports should have been reflected in the # of credit hours the course is worth."
- "The research reports helped to distribute the marks."
- "Research reports were helpful in the understanding of technology used in the engineering field (ex. I have never even heard of thermocouple before and I never knew how strain gauges actually worked.)"

- "Learned lots more from the lectures and research reports than the labs."
- "The research reports, at first, were very hard and they took me a long time. As time went on, I got better at it."
- "Research reports were vague, not very useful."
- "One thing that may improve this class is give less info & tie in to the research report. It kind of gets a little loose at the end of it."
- "Learned a lot from the research reports."
- "The ability to write a longer research report would be enjoyable."
- "Like having the research reports instead of more regular classes/tests."
- "Research reports on sensor technologies provided an opportunity to learn about fundamental measurement principles that I had otherwise not learned about in other classes."
- "The reports (labs and research) did help understanding of previous classes."