Continuing laboratory changes: looking forward and back

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Abstract

While laboratory courses are an invaluable hands-on experience for students, they can also be a significant strain on faculty time, especially when help from teaching assistants is limited. Additionally, aging equipment can be difficult to maintain, and may detract from the student learning experience. In a previous paper, several changes to laboratory experiments were proposed, with the goals of improving the student experience, lab sustainability, and instructor workload, while also being mindful of the new ABET criteria. This paper reports on some of those changes that have been implemented, some that are still in progress, and thoughts for more changes to come. In particular, one experiment was partially replaced in an A-B style test, and student and instructor feedback are discussed. Other planned changes have not yet been implemented, but plans and current progress are shared.

Keywords

mechanical, laboratory, experimental design, ABET

Introduction

At Mercer University, the mechanical engineering curriculum includes two experimental laboratory courses, the first typically taken in the spring semester of the junior year (with an associated lecture), and the second in the fall semester of the senior year. In previous work[1], it was explained why changes to both courses were desired, and plans to implement certain changes were set forth, along with methodology to evaluate those changes. This paper discusses the progress made toward those goals, feedback from implemented changes, and changes to the original plans.

Background

Each spring semester, a junior lab and accompanying lecture are offered to students as part of their required mechanical engineering curriculum. These courses focus on methodologies for performing and analyzing experimental measurements, and six laboratory experiments are conducted over the course of the semester. It was previously proposed[1] to replace an experiment analyzing refrigeration cycles either with one in which the students analyze a fluid flow cycle, or with an acoustics experiment. Additionally, it was proposed that a fourth poster presentation of their results be replaced with an executive summary. Faculty feedback for both changes, and a student survey for the experiment change, were proposed to be used as evaluation measures for these changes.

Each fall semester, a senior lab course is offered, in which students design or develop two sets of laboratory procedures or experiments to accomplish a larger goal. It was proposed to change one of these goals into two shorter tasks in order to provide more feedback and experience with developing sets of multiple experiments. Additionally, it was proposed to change the second task from a thermal fluids lab (free convection and finding properties of a fluid) to a fluids/pump related set of experiments, with details yet to be determined. Feedback for these changes were to include instructor opinions, as well as feedback from the annual ABET evaluation of this course for criterion 3(6).

Changes implemented and results

Two changes to the junior lab course were implemented in the Spring 2019 semester. First, an executive summary report was used for some course sections in place of the fourth lab poster presentation. Second, some student groups performed a fluid dynamics experiment in place of the refrigeration experiment.

For the fourth experiment, approximately half of the student groups were told to submit an executive summary, while the other half gave a poster presentation as they had for the previous three experiments. These students were split by course section, so each faculty member had only poster presentations or executive summaries. Faculty opinions were mixed for this change, based on various logistical issues and opinions. No formal student feedback on the change was requested, but many students complained that the length restriction on the executive summary was too short (the faculty disagree), and several groups turned in work longer than the maximum prescribed length.

In addition to the executive summary test, a refrigeration experiment was compared to a new fluids experiment. The refrigeration experiment was conducted using a P.A. Hilton Ltd. Refrigeration Laboratory Unit. The test rig allows students to adjust water flow through the condenser and/or heat transfer in the evaporator (via electrical heating) while measuring condenser and evaporator pressures, flow rates of the refrigerant and condenser water, readings on the compressor (dynamometer, tachometer, and motor wattage), and temperature at various states within the cycle. They were given two weeks to accomplish their task, with the first week focusing on familiarization of the rig and establishing uncertainty while the bulk of the data collection occurred on the second week. The students were tasked with plotting the coefficient of performance versus some other system property. Since there are multiple redundant sensors on the rig, students can take different paths to the solution, or check their answers using the redundant measurements.

A fluid dynamics experiment was created as a replacement candidate for the refrigeration experiment. The new fluid dynamics experiment utilizes an aquarium pump submerged in a bucket of water that develops enough pressure head to push water up a fluid column as illustrated in Figure 1. The pump is connected to GFCI-protected wall power via a cable attached to an AC power meter, allowing students to track the power input to the pump. A T-connection splits the flow in two directions. One direction leads to the water column where students can measure the height of the fluid being pushed by the pump. The other leads to an output hose where students can determine the flow rate at the pump by measuring the amount of water that exits the output (via a bucket and scale, for instance). Students control the flow using a ball valve, and are asked to determine the pump efficiency as a function of some other system parameter (*e.g.*, flow rate or pressure head). These calculations are performed by performing energy balances at various stages of the flow cycle.

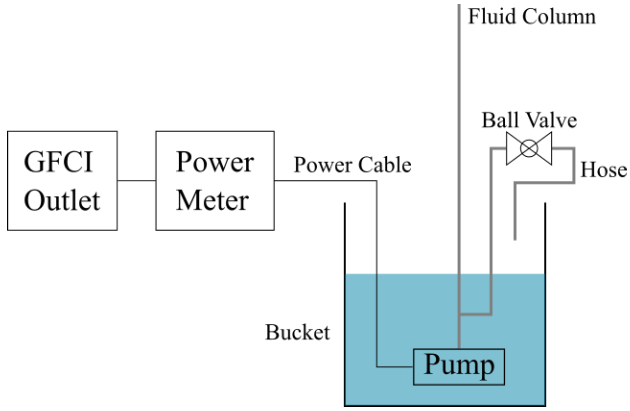

Figure 1: Pump experiment schematic diagram.

To test the proposed replacement experiment, the student groups were assigned to perform either the refrigeration or the fluid dynamics experiment. Video instructions were provided for both experiments so that students would only have to listen to one set of instructions. Instructor feedback was considered in the evaluation of the experiments, as well as student feedback in the form of a survey.

The instructors feel that the fluid dynamics experiment presents more interactive opportunities than the refrigeration experiment. The pump rig has to be partially assembled, which gives students a preliminary hands-on moment to see how the system operates. Additionally, students are able to see a physical result of the pump by how high the water is pushed. The condenser and evaporator on the refrigeration rig do get hot and cold, respectively, but otherwise the students are not able to directly see the effects of the cycle during steady-state operation. When the refrigeration rig is shutting down, the students are able to see bubbles form in the condenser flow meter, but beyond that the students are unable to see the effects of heating and cooling on the working fluid. For both experiments, students required significant feedback during the planning and execution of their experiments, as the introductory material to both experiments was intentionally limited in the amount of subject review presented. Another advantage of the fluid dynamics experiment is that it will be significantly less expensive to produce, modify, and maintain experimental test rigs for the experiment. While the refrigeration experiment is valuable for students to see how key thermodynamic and heat transfer concepts come together to make a very important cycle, the students will get a chance to perform another heat transfer lab in their senior curriculum, and replacing it with the fluid dynamics experiment will give students more insight into fluid dynamics concepts instead.

Student feedback in the form of survey responses is shown in Table 1. Average response values are given for each question, with a value of 3 being "neutral". The actual survey asked students to circle words describing their responses (see table caption), but for brevity these have been converted to numerical results. While some answers are "negative" for both experiments (difficulty and clarity of instructions), the fluid dynamics experiment is uniformly rated higher than the refrigeration experiment in all categories (other than responses to question 10, which are not reported here, as it would be difficult to quantifiably summarize them as supporting one experiment above the other).

Table 1: Student responses to survey questions. Responses were assigned numbers from 1 to 5, with 3 being the neutral answer, 1 being the most "negative" (difficult/unclear/worse/insufficient), and 5 being the most "positive" (easy/clear/better/sufficient). Where "not sure" was an option (questions 4 and 9), only submitted answers were averaged, and the percentage of "not sure" responses were reported below.

No.	Question	Refrig	Fl Dyn
1	Which experiment did your group perform? [number of responses]	[18]	[17]
2	Please rate the difficulty of developing an appropriate methodology for your experiment.	2.33	2.53
3	Please rate the difficulty of obtaining sufficient and useful results for your experiment.	2.39	3.35
4	Please rate the difficulty of your experimental assignment versus the other option (pump/refrigeration). Your experience was _______ to/than the other option.	2.43	3.60
	(Percent not sure, Question 4)	64.7%	41.2%
5	Please rate the clarity of assignment instructions that were given for your experiment (handout, video, verbal, etc.).	2.33	2.88
6	Please rate how sufficient the explanation and/or review of material was to allow you to develop a methodology and interpret results (handout, video, verbal, etc.).	2.72	3.00
7	Please rate the quality of learning experience of this experiment with regards to learning about refrigeration/pump analysis.	3.47	3.76
8	Please rate the quality of learning experience of this experiment with regards to learning about experimental measurements.	3.28	3.53
9	Please rate the overall quality of your learning experience compared to those who were assigned to the other option (pump/refrigeration). Your experience was _______ to/than the other option.	2.60	3.55
	(Percent not sure, Question 9)	76.5%	35.3%
10	Please leave additional comments below or on the back if desired.		

Changes not implemented

Some of the proposed changes have not currently been implemented. In the junior lab course, the acoustics experiment was omitted, so the refrigeration experiment was compared only against a fluid dynamics experiment. None of the proposed senior lab course changes was implemented for the fall 2019 semester. Plans for moving forward with the unimplemented changes are discussed below.

Future plans, timeline, and evaluation criteria

As none of the planned changes to the senior lab course has been implemented thus far, these shall be discussed first. The proposed change from a free convection focus to a different set of fluids experiments is still considered desirable, but will probably not be actively pursued for the next academic year. After considerable discussion among the faculty, it was also decided not to shorten either set of senior lab experiments, and to instead consider including the proposed shorter task (determination of the centroidal moment of inertia of a plate) as one of the junior lab experiments.

Regarding the proposed change from poster presentation to executive summary on the fourth experiment, because of mixed faculty opinions, further discussion is needed to determine if any permanent changes will be made. However, if the executive summary is continued, the maximum length will probably be slightly increased, and additional instruction should also be given to students on how to prioritize the importance of different information in a report.

Based on instructor and student feedback, the fluid dynamics experiment is planned to entirely replace the refrigeration experiment for future semesters in the junior lab. Some further improvements are planned for the pump rig, including adding pressure and flow sensors, and improving the mounting of tubing, valves, and instrumentation on the rig.

Some other changes are still under consideration for the junior lab course. As mentioned above, a current experiment may be replaced with the experiment in which students are tasked with finding a plate’s centroidal moment of inertia. This experiment would require a least two separate experiments, and, while simple, would help provide a framework for planning sets of experiments, and thus hopefully enhance students’ understanding of what is needed to plan sets of experiments for their senior lab courses. Additionally, a short experiment may be added in which students must choose equipment and procedures based on calculations of the expected uncertainty of the results. This is because many students currently in the senior lab fail to understand how their experimental designs are affecting the precision of their results until long after the experiment is conducted (if even then). The previously proposed acoustics experiment is still under development, and may eventually become a part of the junior lab as well, but that change is probably at least a year away.

Conclusion

Out of several changes proposed for a set of junior and senior mechanical engineering lab courses, changing from a refrigeration analysis lab to a fluid dynamics lab (pump efficiency analysis) has proved to be a very successful alteration, with hopefully additional improvements to come. The authors continue to consider other proposed changes, and hope to continue improving these two courses in current and future academic years.

References

1. Marek, Kenneth, "Laboratory changes: Sustainability, Streamlining, and Satisfying ABET", *Proceedings of the ASEE Southeastern Section Annual Conference 2019*, March 10-12, 2019, Raleigh, NC.

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