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Voice of the Students: Continuous Lab Course Improvement Using Student Feedback

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The educational benefits of laboratory courses are well established, but their high infrastructure and equipment needs can be a barrier to innovation, causing the courses to stagnate over time. Standard course evaluation feedback is not detailed enough to gauge the effects of lab experiment improvements on student learning. This study presents a methodology for continuous improvement of a lab course. Students were initially asked to provide their own edits to existing lab handouts, which were compiled to determine common points of confusion from the student perspective. This input, as well as voice of the customer data from focus groups, was used during the development of new labs. The response to the new labs was monitored via surveys each subsequent term. Surveys were designed to elicit experiment-specific responses such as whether students felt they learned from the experiment, whether the experiment was frustrating or engaging, and if they could use the information from the lab in future work. Six years of survey data was used to determine correlations between lab aspects and student outcomes. There were strong correlations ($R^2 = 0.79$) between lab activities that students felt helped them learn and activities they felt might be applicable to problems outside lab. There were also moderately strong correlations ($R^2 = 0.47$) between grades on an open-ended experimental design project and lab activities that were perceived as applicable to outside problems. Additionally, the survey data demonstrated that the benefits of new lab experiments developed with student feedback and input are sustainable over time. Finally, this methodology allowed for rapid identification of problems in the course and a timely assessment of course improvements. This methodology is easily adaptable to any lab course and can indicate where limited time and resources should be directed for maximum impact.

Introduction

Laboratory classes are a key component of mechanical engineering programs. Although they have proven educational benefits, and are generally required for accreditation, they represent a substantial commitment of space, resources, and personnel. Because of the effort and financial investment involved in developing new lab experiments, it is easy for labs to stagnate and become out of date. Virtual labs and simulations have been used to combat this in many cases but hands on and open ended experiments still have immense value for student learning.

In their 2005 paper Feisel and Rosa outlined fundamental objectives for engineering laboratories. These objectives include: proficiency in the use of instrumentation, the ability to compare theory and real world behavior, proficiency in developing experiments, data analysis abilities, design abilities, the ability to learn from failure, creativity in developing solutions, the ability to choose and use appropriate engineering tools, the ability to consider safety issues in experimentation, proficiency in technical communication, teamwork ability, the ability to perform research ethically, and the ability to gather information and use it to make justified engineering decisions.[1] In order for a laboratory experience to satisfy these objectives, experiments should involve opportunities for students to explore their own ideas, control the outcome of the experiment, and solve open ended problems when possible.

Typical lab experiments tend to fall into four basic categories. Expository lab experiments, sometimes referred to as 'cookbook' experiments, provide students with a set procedure and tend to have a predetermined outcome. Inquiry type experiments require students to develop their own laboratory procedures, predict the outcome, and use the results to derive principles. Discovery type experiments also have predetermined outcomes and set procedures, but students are meant to use them to discover principles, rather than reinforcing existing knowledge. Problem-based experiments have desired outcomes, but expect the students to generate the procedures to solve the problem.[2] Although all four types of experiments have value, inquiry experiments tend to be the closest to what is typically seen in graduate level and professional research. Unfortunately, these experiments can be difficult to offer and administer in the undergraduate curriculum due to limited time and space, and the less controlled nature of these type of experiments. The challenge then becomes one of making labs as open ended and unscripted as possible within the constraints of the course and the available resources.

Abdulwahed and Nagy developed a model for developing laboratory experiences that relied on Kolb's experiential learning cycle.[3] Kolb's learning cycle describes moving from concrete experiences to reflective observation to abstract conceptualization to active experimentation.[4] Students need to come to an understanding of why the material is important to learn, to learning important new concepts, to using the concepts for active experimentation before making new connections and using the newly acquired knowledge for other purposes. By their nature, lab experiments tend to focus on the active experimentation portion of the cycle. However, active experimentation is going to be less effective for learning unless students are given the opportunity to access the other portions of the cycle through purposefully designed activities.[3] When new labs are developed or old labs redesigned, there is an opportunity to choose experiments and activities that use all aspects of the learning cycle, rather than focusing solely on a perhaps limited experiment.

An experiment can be designed well on paper but still be received poorly by students. It is therefore important to incorporate student views into the design of laboratory experiences. Voice of the student input has been used for evaluating course management systems [5] and for improving student satisfaction at a university wide level.[6] For individual courses the use of course evaluation forms administered by the university is a common form of feedback from the students. However, these course evaluations tend to focus on the course as a whole and the quality of the instructor, but may lack sufficient resolution to determine the portions of the course that require most attention. The current work describes an effort to jump start a major course redesign using voice of the student input followed up by systematic surveying of lab students to focus attention on the biggest problems. Combining this student feedback with best practices for laboratory instruction should allow for focused and timely improvement of laboratory quality.

Course Details

ME4505 Measurements and Analysis with Thermal Science Application is a required laboratory course at Northeastern University. The course consists of three lectures and one two-hour laboratory session per week. The aim of the course is to introduce students to experimental design, data analysis, data acquisition systems, and specific techniques and sensors for measuring common engineering quantities such as pressure, strain, temperature, etc. In addition, this course serves as the primary lab experience in thermofluids, covering experimental techniques for measuring heat transfer coefficients, analyzing heat exchanger efficiency, and measuring wind turbine behavior in a wind tunnel. A term long group project requires students to develop, execute, and report on a measurement experiment of their own choosing. This course is designed to particularly prepare students for their senior year capstone design experience by giving them practice in open ended projects and higher level analysis skills. The author has taught this course as the sole instructor since Fall 2010.

ME4505 has seven major lab experiments during the course. During pre-lab homework assignments, students develop data tables and procedures, perform sample calculations, and identify key variables. Lab 1 involves measuring mechanical power using a bicycle powered generator and introduces students to oscilloscopes and other common measurement tools.[7] The subject of Lab 2 is pressure measurement with a particular emphasis on calibration techniques. Lab 3 introduces strain measurement and Wheatstone bridge circuits for sensors. [8] Lab 4 introduces temperature measurement devices and dynamic measurements, including time constants and first order measurement systems. In Lab 5 students measure heat transfer coefficients of a heated cylinder in cross flow, and also get practice in connecting theoretical heat transfer to experimental results.[9] In Lab 6 students compare horizontal and vertical axis wind turbines in a wind tunnel.[10] Finally, Lab 7 measures efficiency in a small heat exchanger, and also gives students practice in writing experimental procedures. The labs are designed to be progressively more open-ended and are linked to the lectures to reinforce key concepts. The first three lab experiments require submission of individual lab reports by each student, while the last four experiments require one report per lab group.

The course has been a staple in the curriculum for many years, but underwent a major redesign in Fall 2011. The primary goal of the redesign was to move from demonstration type labs to open ended and hands on lab experiences, as described in previous work by the author.[11] In Fall 2014, the TopHat classroom engagement tool was introduced in order to automate and expand in-class participation. The Vernier SensorDAQ [12] data acquisition system was introduced in Fall 2016. Each lab group is issued a SensorDAQ for the term, to be used for experimentation both in lab and outside of lab during project work. In addition to the introduction of major new elements such as TopHat and the Sensor DAQ, alterations and improvements have been made to the lab experiments as needed.

Method

As stated, the course was redesigned in Fall 2011, using feedback gathered from students during Fall 2010 and Spring 2011. No data was available prior to Fall 2010. During Fall 2010, students were offered the chance to earn bonus points by printing out the lab handouts and annotating them to reflect things that were unclear, poorly written, or irrelevant. The feedback was compiled and used to redesign the lab handouts without changing the experiments. During Spring 2011 a student focus group was convened to determine attitudes toward experiments in the course in question and in other lab courses in the department. This is described in detail in a previous work by the author [11].

During the initial redesign of the course a survey was administered to the students near the end of the Spring 2011 term to determine their attitudes about the lab experiments. This anonymous survey was repeated in every subsequent term. The following statements were rated by the students on a 5 point Likert scale from 'Strongly Agree' to 'Strongly Disagree' for each individual experiment.

1. This lab helped me learn the material
2. This lab was interesting and engaging
3. This lab was frustrating and confusing
4. This lab was supported by lecture
5. I can imagine applying some of this information to other problems

Two additional open ended questions were also asked. The first was "Can you think of any topics/experiments that you would like to see added to the course?" The purpose of this question was to ensure that future course improvements are aligned with student needs and interests if at all possible. The second question was "Do you have any other general ideas on how to improve the lab experience in all of MIE? (Ideas: different facilities, different offerings, something you need from TAs or professors, etc.)". This information is used by the departmental lab director to guide department wide efforts to improve lab experiences.

The responses to the Likert scale questions over time were analyzed for their correlation to each other and to various course outcomes using the Pearson Product-Moment Correlation Coefficient implemented with the Excel correlation analysis. The course outcomes considered were average project grades, average grades for individual lab experiments and average grades for the related pre-lab homework assignments. The analysis was focused on labs that had had sufficiently similar content for a substantial number of terms, to avoid directly comparing labs that were completely dissimilar. These labs included the Pressure lab, the Temperature lab, the Strain lab, the Mechanical Power lab, and the Wind Tunnel lab. The responses to the open-ended survey questions were also analyzed for common themes and other insights.

Results

The survey results for the past 13 terms are presented below for the five labs studied. In all cases, the figures present the percentage of respondents that indicated 'Agree' or 'Strongly Agree' on the Likert scale in response to the prompt.

Figure 1 shows the results for the Pressure lab. This lab has typically been offered as either the first or second lab in the term, and introduces calibration and data acquisition with LabView. The initial form of this lab in Fall 2011 was based around a single large board that included a number of different pressure sensors. Since there was only one board, the entire lab section of 12-16 students was grouped around this one board, and thus the opportunity for open ended student interactions was severely limited. In Fall 2011 the labs were completely redesigned, leading to a large increase in the number of students who found the lab interesting and engaging and who found the lab helped them learn. Additional increases in the students' perception of the lab as interesting and engaging were seen after major course additions such as the TopHat engagement tool and the SensorDAQ. The TopHat tool in particular was used for doing small group calibration experiments during lecture, which improved student knowledge prior to entering the lab and led to nearly all the students finding that the lab was strongly supported by lecture. The number of students who found the lab frustrating and confusing decreased to a very low level that was maintained over time.

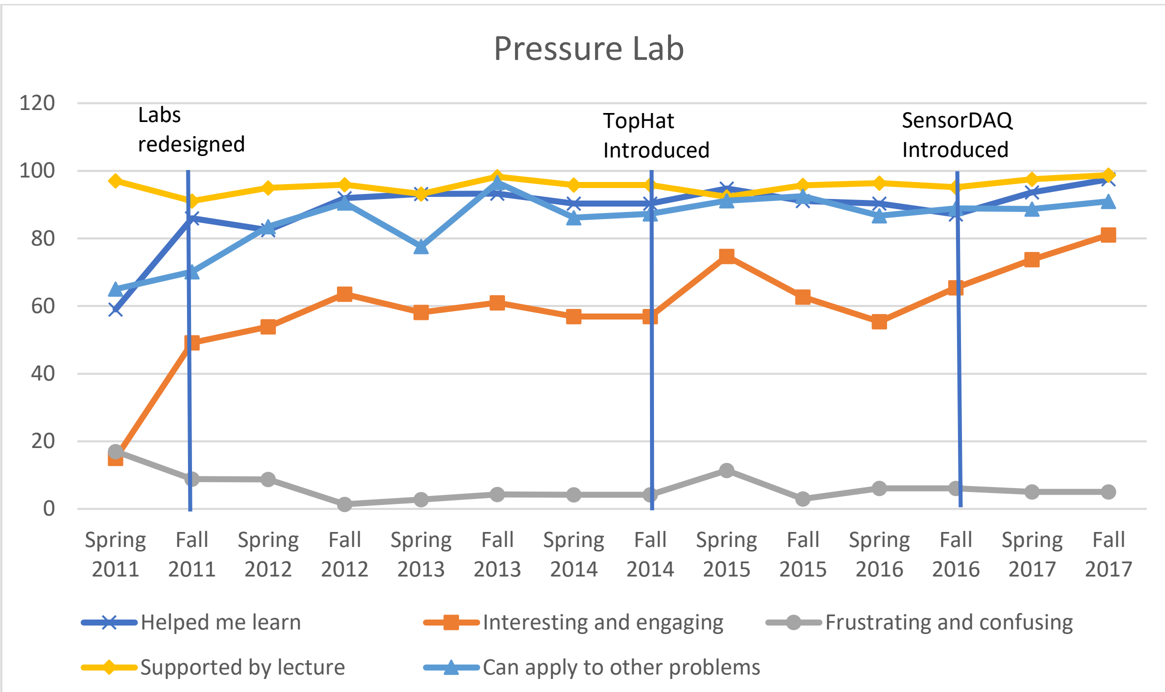

Figure 1: Percent of respondents who Strongly Agree/Agree with prompts over time for the Pressure Lab

Figure 2 shows the results for the Temperature lab. The improvement in engagement, perception of learning value, connection to lecture, and ability to potentially use information in other situations all improved after the redesign of the lab experiment, and some of the improvements were quite dramatic. In Fall 2013 the experiment was slightly revamped to include measurement of time constants in a first order system. Initially this caused an increase in the frustration and confusion expressed by the students. In response to the survey after the initial revamping, the lab handouts and other experimental details were improved. This is reflected in a gradual increase in the perception that the lab was interesting and engaging, and the lab has become more stable over time. Improvement was also seen in certain measures after TopHat was introduced, although the effect is less clear.

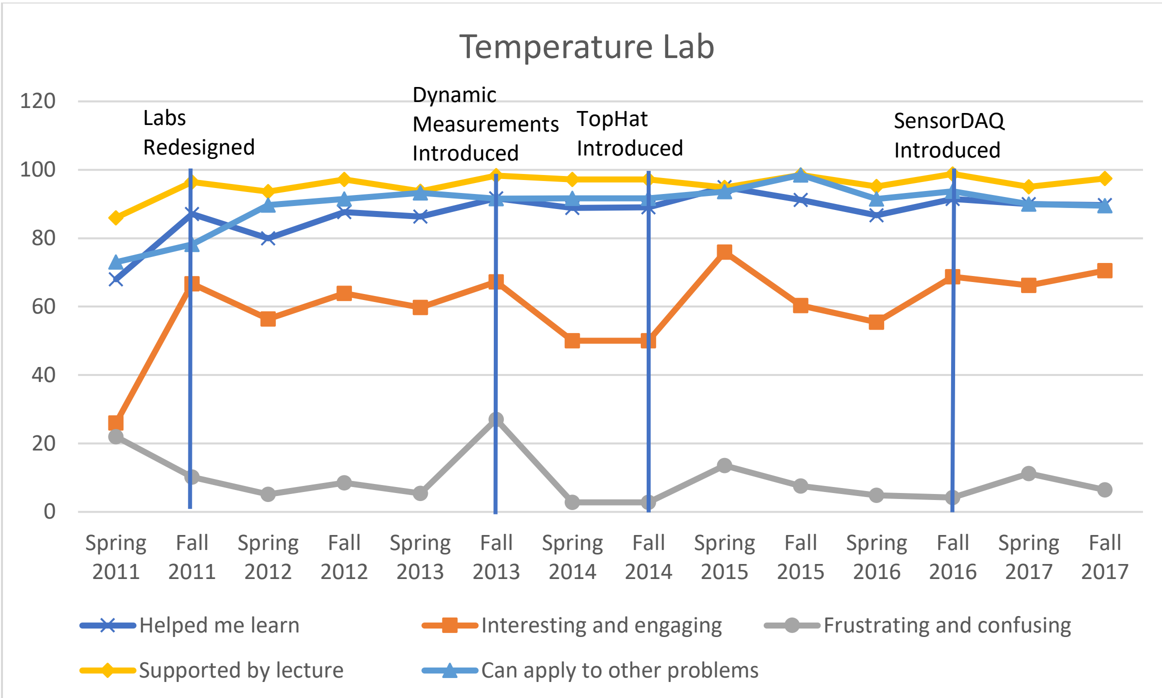

Figure 2: Percent of respondents who Strongly Agree/Agree with prompts over time for the Temperature lab

The results for the Strain lab are shown in Figure 3. Reduction in the amount of frustration and confusion was immediate and dramatic after the redesign of the labs, due to improved lab handouts, and the replacement of an overly constrained cookbook type experiment with a more open ended experiment. The new experiment used robust strain indicator boxes which allowed students to be able to connect and disconnect strain gauges from the circuit themselves without risking damage to expensive strain modules connected to a desktop computer. Previously all circuits had to be prewired by the technicians to avoid damage to the strain modules, which severely restricted the student involvement in the experiment. This is reflected in the engagement scores as well as the perception that the lab was widely applicable and helped them learn. The effect of the introduction of TopHat was mixed, with interest and engagement improving and other positive measures staying relatively constant. Frustration and confusion initially increased. This may be because the theoretical model discussed in class and used for the TopHat discussions in class ended up being substantially different than the actual behavior of the setup in lab. After survey results indicated the excessive frustration that resulted, the presentation of the theoretical model was improved and the connection to other points in the curriculum was made more concrete. The strain lab has always been one that was difficult for the students, as it relies on circuits concepts that not all students have had at this point in their curriculum. However, by using the survey data to pinpoint areas that require improvement, the perception of the lab as interesting, engaging, and helpful for the learning experience has improved steadily over time and is being maintained at a much higher level than the lab started at.

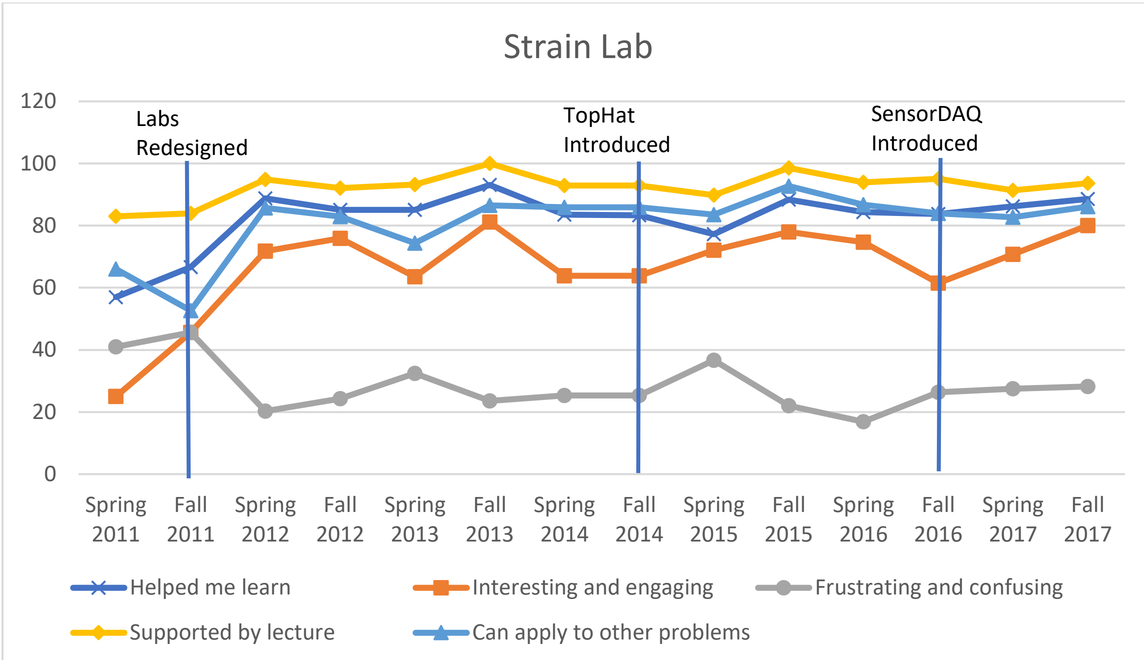

Figure 3: Percent of respondents who Strongly Agree/Agree with prompts over time for the Strain Lab

Figure 4 shows the results from the Mechanical Power Lab. The redesign of the lab in Fall 2011 changed the lab so substantially that no direct comparison could be made to the previous experiment. The current Mechanical Power Lab introduces methods to measure rotational velocity and electrical and mechanical power. Previously these concepts were taught in two separate demonstration type labs on Rotational Velocity measurement and Fluid Power measurement. These were replaced by an extremely active, hands on lab where students rode a bicycle powered generator and measured rotational speed and power generated by multiple methods. As is common with new labs, the first few offerings were initially perceived as more frustrating and confusing as the minor issues were worked out. There was a minor improvement in positive aspects after TopHat was introduced. The effect of the incorporation of the SensorDAQ was minimal on this experiment. This is the first experiment in the course, and the SensorDAQ is not used for it, which allows the students sufficient time to learn and practice programming in LabView. This lab is a good example of one that was rapidly improved with the help of survey information and has been maintained at a reasonably high level over a long period of time.

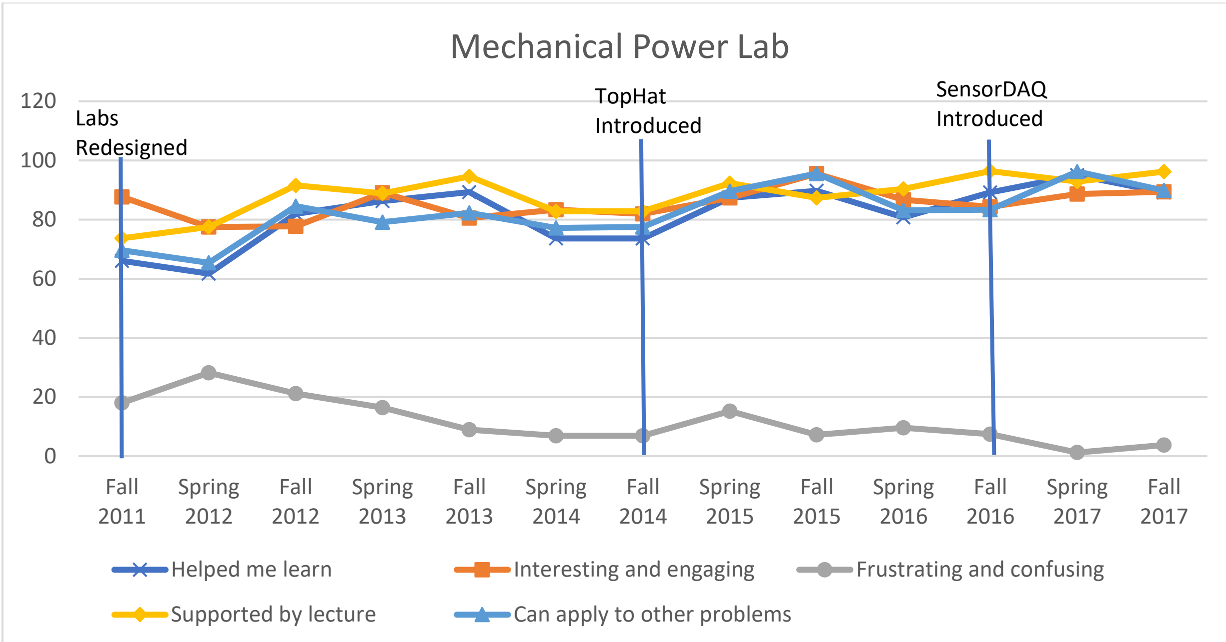

Figure 4: Percent of respondents who Strongly Agree/Agree with prompts over time for the Mechanical Power Lab

The results for the Wind Tunnel Lab are shown in Figure 5. No survey data was available prior to Fall 2012. The experiment originally involved students measuring the drag force generated by a model car before and after altering the car to improve aerodynamics. This lab had been positively rated by the students when the course was originally taken over by the new instructor in Fall 2010. Because of this the experiment was initially unaltered except for rewriting the lab handouts. In Fall 2013, the wind tunnel was altered in order to accommodate a larger cross section for a research project. This reduced the maximum wind speed in the tunnel, which made the data gathered during the experiment less reliable and made the differences between the altered and unaltered car less noticeable. This was reflected in an increase in frustration and a decrease in the perception that the lab helped them learn. Student comments on open ended questions also indicated that the lab was becoming an exercise in trying to coax data out of a setup that was no longer viable. Some alterations to the setup including new sensors and lighter cars improved student attitudes somewhat. Ultimately the decision was made to create a new experiment in a smaller wind tunnel which had a higher wind speed. A wind turbine was introduced to tie into the creation of an Energy Systems minor in the department. Initially this resulted in a decrease in the interest and engagement metric. This may be due to the fact that the initial offering of this experiment required a high level of technician involvement. As has been seen in other experiments, students dislike experiments that reduce them to spectators. The second iteration of this new experiment in Spring 2017 has already showed an improvement in the positive survey items and a decrease in the frustration level. This lab is still being improved in response to the student input.

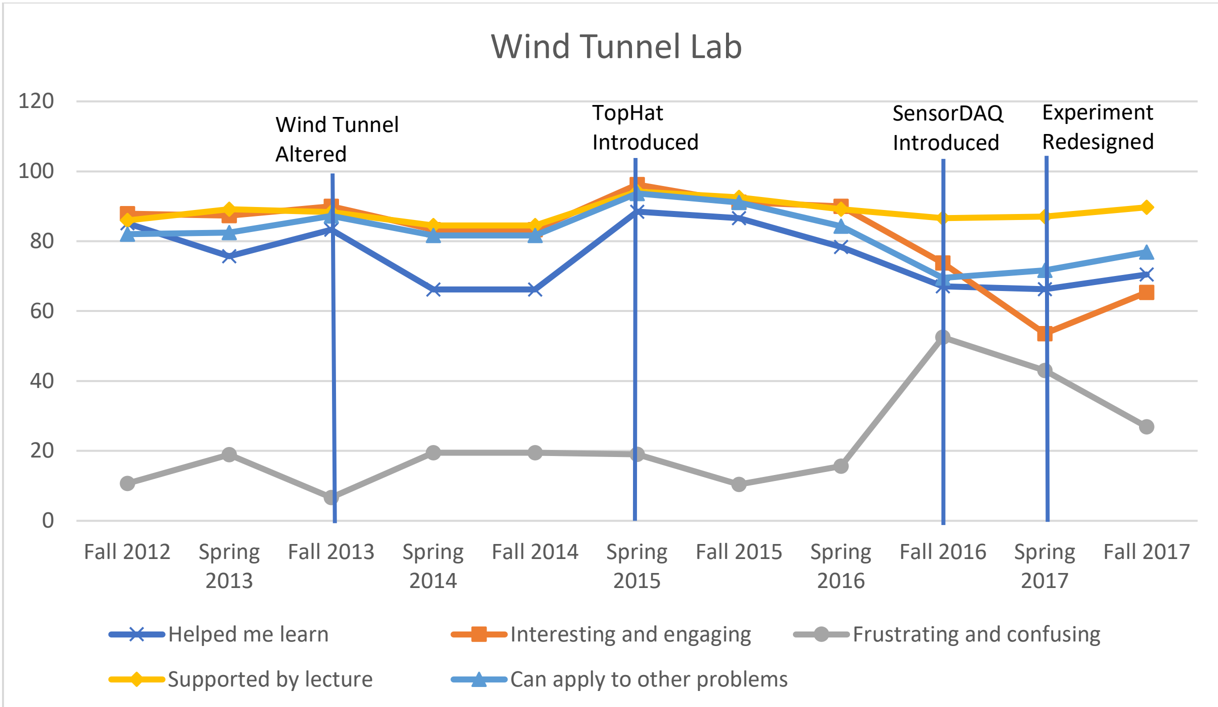

Figure 5: Percent of respondents who Strongly Agree/Agree with prompts over time for the Wind Tunnel Lab

Pearson' Product-Moment correlation coefficients were calculated to determine whether certain factors were correlated. The results of this analysis were different for each lab experiment examined. Table 1 shows the results for the Pressure lab. Only results with a P value < 0.1 are shown. Strong positive correlations were seen between students finding the lab interesting and engaging and students feeling that the lab helped them learn, and between the perception that the information could be applied to other problems and that the topic was well supported by the lecture. Moderate positive correlations were seen among various factors, although only the correlation between students feeling the material could be applied to other problems and students finding the material interesting and engaging was statistically significant. Students who found the lab was not supported by lecture did not tend to find it frustrating and confusing, as evidenced by the negative correlation, although the result was not quite significant.

Table 1: Pearson's Correlations for Pressure Lab. Only correlations with P < 0.1 are shown.

Paired Factors	**R^2**	**P (α=0.05)**
Interesting and engaging/Helped me learn	0.75	0.003
Can apply to other problems/Supported by lecture	0.71	0.006
Can apply to other problems/Interesting and engaging	0.59	0.03
Lab Average/Helped me learn	0.54	0.06
Project Average/Interesting and engaging	0.50	0.08
Supported by lecture/Frustrating and confusing	-0.50	0.08
Can apply to other problems/Helped me learn	0.49	0.09

Table 2 shows the correlations for the Temperature Lab. For this particular lab there were no strong correlations. The only significant correlation was a negative correlation between the lab average and the homework average. This correlation cannot be readily explained. Two nearly significant correlations are worth discussing. There was a positive correlation between students finding the lab interesting and engaging and finding that it helped them learn, as was seen in the Pressure lab. However, there was also a positive correlation between finding the lab interesting and engaging and finding it frustrating and confusing. The Temperature Lab has had many small changes over the years, and these changes may mean that the various terms are not directly comparable to each other.

Table 2: Pearson's Correlations for Temperature Lab. Only correlations with P < 0.1 are shown.

Paired Factors	R^2	P (α=0.05)
Lab Average/Homework Average	-0.57	0.04
Interesting and engaging/Helped me learn	0.53	0.06
Frustrating and confusing/Interesting and engaging	0.54	0.06
Supported by lecture/Helped me learn	0.52	0.07
Project Average/Homework Average	-0.55	0.07

The correlation results for the Strain Lab are shown in Table 3. There were many strong correlations that were statistically significant. Strong positive correlations were found between feeling that the lab helped them learn and feeling that it was supported by lecture, interesting and engaging, and could be applied to other problems. This topic tends to be difficult for the students, so it makes sense that being well supported by lecture is important. There were strong negative correlations between students who found the lab frustrating and confusing and those who thought it helped them learn or that that the information could be applied to other problems. Students who felt positively toward the lab tended to see the information as broadly applicable to other problems. This lab, while it can be difficult and frustrating for students, also seems very rewarding and interesting to students when they master it.

Table 3: Pearson's Correlations for Strain Lab. Only correlations with P < 0.1 are shown.

Paired Factors	R^2	P (α=0.05)
Supported by lecture/Helped me learn	0.90	0.00
Can apply to other problems/Frustrating and confusing	-0.83	0.00
Interesting and engaging/Helped me learn	0.81	0.001
Frustrating and confusing/Helped me learn	-0.81	0.001
Can apply to other problems/Helped me learn	0.81	0.001
Can apply to other problems/Interesting and engaging	0.81	0.001
Can apply to other problems/Supported by lecture	0.80	0.001
Supported by lecture/Frustrating and confusing	-0.78	0.002
Supported by lecture/Interesting and engaging	0.72	0.006
Frustrating and confusing/Interesting and engaging	-0.67	0.01
Project Average/Homework Average	0.54	0.08

Table 4 shows the correlations for the Mechanical Power lab. This lab had strong positive correlations between students that felt the lab helped them learn and the lab being supported by lecture and applicable to other problems. Seeing the materials as being strongly supported by lecture was also positively correlated with a high homework average and being applicable to other problems. Students who see the lab as frustrating and confusing did not seem to think it helped them learn and found it less interesting and engaging. As this is the first lab in the course, it is important to minimize frustration, as at this stage frustration is seen less as a challenge and more as an indication that the instructor or the lab technicians have not done their job. In later labs, frustration does not necessarily equate with lower positive outcomes.

Table 4: Pearson's Correlations for Mechanical Power Lab. Only correlations with P < 0.1 are shown.

Paired Factors	R^2	P (α=0.05)
Supported by lecture/Helped me learn	0.89	0.00
Can apply to other problems/Helped me learn	0.90	0.00
Can apply to other problems/Supported by lecture	0.74	0.003
Homework Average/Supported by lecture	0.74	0.003
Frustrating and confusing/Helped me learn	-0.64	0.02
Homework Average/Can apply to other problems	0.62	0.03
Homework Average/Helped me learn	0.58	0.04
Can apply to other problems/Interesting and engaging	0.59	0.04
Supported by lecture/Frustrating and confusing	-0.66	0.08
Frustrating and confusing/Interesting and engaging	-0.49	0.09

Table 5 shows the correlation results for the Wind Tunnel Lab which had a number of strong correlations, both positive and negative. Students who found this lab frustrating and confusing tended to have very negative opinions of it as evidenced by the negative correlations. This lab can be inherently frustrating because there is only one wind tunnel available. This means that even with the best possible scheduling there are always times when students are standing around doing nothing, which is universally disliked. This lab also has many sensors that must be coordinated, which can be frustrating. Students who had positive attitudes toward the lab tended to have higher homework grades and felt there was more benefit to the lab experience.

Table 5: Pearson's correlations for Wind Tunnel Lab. Only correlations with P < 0.1 are shown.

Paired Factors	R^2	P (α=0.05)
Can apply to other problems/Interesting and engaging	0.84	0.001
Can apply to other problems/Frustrating and confusing	-0.83	0.001
Homework Average/Frustrating and confusing	-0.86	0.002
Can apply to other problems/Helped me learn	0.80	0.003
Homework Average/Can apply to other problems	0.81	0.003
Frustrating and confusing/Interesting and engaging	-0.75	0.008
Interesting and engaging/Helped me learn	0.71	0.01
Homework Average/Helped me learn	0.82	0.01
Frustrating and confusing/Helped me learn	-0.67	0.02
Supported by lecture/Helped me learn	0.70	0.02
Homework Average/Interesting and engaging	0.66	0.03
Lab Average/Homework Average	0.60	0.03
Can apply to other/Supported by lecture	0.61	0.04
Lab Average/Supported by lecture	0.54	0.07
Lab Average/Helped me learn	0.63	0.08
Homework Average/Supported by lecture	0.63	0.08

Discussion

The ultimate goal of the surveys was to continuously monitor and improve the lab course in question. If a lab is consistently rated as frustrating or unengaging, it is worth examining if the experiment itself needs to be modified or improved. End of course surveys do not have the necessary level of detail to track the effect of changes to individual experiments. This level of detail is vital to the improvement of lab experiments, since a significant amount of time, resources, and equipment is needed to bring a new experiment online. For a new instructor, or a course that needs substantial redesign, it is helpful to know where to best focus these limited resources. The surveys were initially used to provide a baseline measurement of which experiments needed to be fixed most urgently. More importantly, they also ensure that changes are sustainable over time.

From the student perspective one of the most important aspects of a lab is whether or not it helps them learn the material. Labs that are disconnected from the course topics or that are seen as busywork are not well received by the students. For all the labs studied except for the Temperature lab, the results indicate that labs helped them learn when the experiment was seen as supported by lecture and interesting and engaging. Labs that help students learn are also seen as having information that is applicable to other problems. This is a particularly valuable outcome for making connections across the curriculum. If students can imagine having to use particular techniques or sensors in other situations, there is a better chance that they will retain that information beyond the course.

Small amounts of frustration can be beneficial, as a disruptive challenge is often necessary for a student to accept a new idea or paradigm. However, when the frustration is seen as unnecessary or the result of incompetence on the instructor's part, the point of the experiment can get lost. The Wind Tunnel, Strain, and Mechanical Power labs had strong negative correlations between students feeling the lab was frustrating and confusing and feeling that the lab helped them learn and could be applied to other problems. These labs either had difficult subjects or had many sensors to integrate and manage. Labs that were conceptually simpler or had fewer types of sensors such as the Pressure and Temperature labs did not seem to elicit as many negative responses.

Student responses to the questions "Can you think of any topics/experiments that you would like to see added to the course?" had several suggestions for simple lab topic additions, such as studying sound, light, or acceleration. However, some of the comments on this and the other open-ended question showed some high level insights into the value of the class to the wider curriculum. For example, several comments recognized and appreciated the fact that the class deliberately drew from other classes in the curriculum:

> "As a student in heat transfer, having the labs tie into that class was super interesting. Having more relevant labs like that could be good."

> "I think the experiments were comprehensive for the courses we have taken. Perhaps another experiment related to beam deformation to reinforce topics from Mechanics of Materials/FEA"

Other students commented on the placement of the course in the curriculum:

> "I think this class should be offered earlier on – it would have helped me understand other material and experience more realistic circumstances before going so in depth in individual classes."

> "I think this would be a great 2nd year course. It introduces basic concepts that can be applied to nearly every aspect of mechanical engineering. I'm nearly done with the ME curriculum and many of the concepts we learned about were somewhat redundant."

This class is currently offered during the junior year, due to scheduling constraints in the broader curriculum. Students and faculty alike recognize that some of the skills taught in this class would be useful prior to co-op or other lab classes. In order to make the class as relevant as possible, the focus of the class has gradually shifted from familiarity with sensors and data acquisition to preparation for the higher level analysis, design of experiment, and statistical analysis skills required for capstone design.

In considering the entire departmental lab experience, students both appreciated the open ended experiments in ME4505 and expressed a desire for more student control of other lab experiments:

> "I feel like more open ended experiments could be useful. Most of the labs we do just test our ability to follow directions which isn't particularly useful long term. I think making more of the labs like lab 7 could help us prepare for the testing we'll need to do later on in our careers."

> "Let students set up the labs and calibrate equipment themselves."

> "In the lower level labs students do not get too much hands on time with the labs. I think it would be better to get the students involved rather than watch a TA run the test."

Comments of this type have been appearing since the beginning of the survey and also on the initial voice of the student focus groups. However, the number of these comments has decreased over time. A concerted department wide effort has been made to increase the hands on nature of all lab courses. Some experiments are easier to make hands on than others. For example, experiments involving the large Instron testing frame are difficult to make hands on due to the small number of machines. Improvements to these types of experiments have focused on using small scale testers to allow for more student interaction combined with scheduling changes to increase the access to the large machines.

Very few responses indicated difficulty with specific lab experiments in the course. The one experiment that did draw several comments was the wind tunnel lab, which was the lab most recently modified. This lab used to have students measure the drag force on a model car. The new version compares vertical and horizontal axis wind turbines. This lab is typical of new labs in that there were still some minor issues that needed to be worked out. Students tend to be intolerant of equipment that does not work as they expect. Typical comments include:

> "The vertical wind air turbine did not seem to work well in the wind tunnel lab."

> "Improve the setup of the wind tunnel and crossflow labs. Especially the vertical axis turbine."

Even though several students were frustrated with the wind tunnel experiment, the survey results showed how the feedback process can lead to rapid improvement. This experiment was first introduced in Spring 2017. During that term, 66% of the students agreed or strongly agreed that the lab helped them learn, 54% found that it was interesting and engaging, and 43% found it frustrating and confusing. Using the feedback from the initial offering of the experiment, improvements were made to the sensors, the connection of the wind turbine to the tunnel, and the organization of the lab. By the second offering of this experiment in Fall 2017, 71% of the students found that the lab helped them learn, 65% found it interesting and engaging, and only 27% found it frustrating and confusing. Future iterations will continue to improve the student engagement and perceived value of the lab while reducing the frustration factor as much as is practical.

Conclusions

This survey has proven to be a simple but powerful method for continuous lab monitoring and improvement in the Measurements and Analysis lab course at Northeastern University. The questions target student attitudes toward the value of the lab, but also serve as a check on the instructor. Adjustments to the lecture topics to promote better tie in to the lab and to the rest of the curriculum can be made if an experiment consistently scores low in the metrics "This lab is supported by lecture" and "I can imagine applying this information to other problems." The results have also indicated that labs need to be interesting and engaging and broadly applicable in order to be perceived as helping students learn. This reinforces the need to develop labs that are open ended and hands on, rather than overly constrained cookbook type experiments. Based on the results of this study, the survey is being extended to other lab courses in the department to gain baseline data to be used for department wide planning and improvement activities. This method engages the learners and the teachers in a cycle that allows real and sustainable lab improvement to be made.

References

[1] Feisel, L. D., & Rosa, A. J. “The role of the laboratory in undergraduate engineering education.”, *Journal of Engineering Education*, 94(1), 2005, pp 121-130.

[2] Domin, D. S., “A review of laboratory instruction styles.” *Journal of Chemical Education*, 76(4), 1999, pp 543-547.

[3] Abdulwahed, Mahmoud, and Zoltan K. Nagy. "Applying Kolb's experiential learning cycle for laboratory education." *Journal of engineering education*, 98.3, 2009, pp 283-294.

[4] Wankat, P. C., & Oreovicz, F. S. Teaching engineering. Purdue University Press, 1993, 99 292-294

[5] Cudney, E. A., & Murray, S. L., & Groner, B., & Kaczmarek, K. M., & Wilt, B., & Blaney, K., & Phelps, J. (2017, June), “Using the Voice of the Student to Evaluate Learning Management Systems”, Paper presented at 2017 ASEE Annual Conference & Exposition, Columbus, Ohio. https://peer.asee.org/29091

[6] Shah, M., & Nair, C. S. “Using student voice to improve student satisfaction: Two Australian universities the same agenda”, *Journal of Institutional Research (South East Asia)*, 7(2), 2009, pp. 43-55.

[7] McCue, K and Smyser, B.M. , “Bicycle Powered Generator: A hands-on experiment in measurement and analysis”, presented at the Bring Your Own Experiment workshop at the American Society for Engineering Education, 2013 Annual Conference and Exposition, Atlanta, Georgia, June 23-26, 2013

[8] Smyser, B. M. (2015, June), “BYOE: Strain Measurement in a Simply Supported Beam”, Paper presented at 2015 ASEE Annual Conference & Exposition, Seattle, Washington. 10.18260/p.23654

[9] Smyser, B.M., “Convective Heat Transfer of a Cylinder in Cross Flow“, Presented at the Bring Your Own Experiment workshop at the American Society for Engineering Education Annual Conference and Exposition, June 2014

[10] Knepple, R.A., McCue, K.F., and Smyser, B.M., “BYOE: Comparison of Vertical- and Horizontal-Axis Wind Turbines, American Society for Engineering Education Annual Conference and Exposition, June 2018, Pending

[11] Smyser, B. M., & McCue, K. (2012, June), "From Demonstration to Open-ended Labs: Revitalizing a Measurements and Analysis Course", Paper presented at 2012 ASEE Annual Conference & Exposition, San Antonio, Texas. https://peer.asee.org/21412

[12] Vernier Software and Technology, SensorDAQ, https://www.vernier.com/products/interfaces/sdaq/, last accessed January 18, 2018.