

Design and Implementation of an Aspirational Ethics Laboratory Course

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Abstract

This paper describes a laboratory course designed to enhance education in a traditional mechanical engineering laboratory focused on controls and instrumentation. The laboratory course and specific modules are part of a broader effort to enhance the mechanical engineering laboratory curriculum with modern pedagogical methods, incorporate ethics through the curriculum, and improve student outcomes.

The laboratory course was designed to inspire a heightened awareness of engineering ethics in addition to traditional controls. A new module has been added that applies the conventional topic of Programmable Logic Controllers in the context of controlling the breathing of an artificial lung.

To assess the laboratory's success a survey was developed for students interacting with the new module. Results indicate the new laboratory experiment has been very successful in improving student awareness of the ethical charge engineers have to perform quality work.

Introduction

This paper provides an overview of a laboratory course in the mechanical engineering curriculum that has been designed over several years to enhance student awareness of ethics in engineering.

A specific laboratory module described in detail is also part of a larger effort by several mechanical engineering faculty to enhance the entire laboratory curriculum and scaffold professional development (including ethics) with technical skills. The laboratory curriculum enhancement includes two facets: (1) Modernize and improve the technical skills acquired by students in the laboratory courses, and (2) thoughtfully incorporate developmental skills (soft skills like teamwork, communication, etc.) that are important for engineers.

The larger pedagogical project uses evidence based instructional methods with an emphasis on backward design. The pedagogical methods are used to create new laboratory modules that use specific learning objectives with open-ended laboratory methods to create experiences where students “cook” without a recipe. The controls laboratory course described in this paper was part of the inspiration for this pedagogical effort with several open-ended laboratory modules that had been developed over time. The prior efforts in the pedagogical project have been described in other papers and include thermal science laboratories and material science laboratories [1].

The research team started working on large curriculum change several years ago and has successfully implemented several more coherent structures including design [2]. The idea of incorporating ethics in several places in the curriculum has been structured in several ways:

- New ethics modules have been developed for specific courses as one or two lecture elements. Whenever possible the modules focus on engineering ethics topics relevant for the course [3]. This paper describes changes to one laboratory course at the junior level as part of this effort.
- Class projects have been modified to help students develop a growth mindset about ethics issues like inclusion. A heat transfer project was modified to help students gather insights about the importance of inclusion over the course of the semester and project.
- An elective class has been developed that allows students to take a leadership role in improving the culture of ethics at the engineering school. In the first offering of the course the students developed an ethics module and video to be presented to second year students [4].

In the junior level ME 351 laboratory course the students have traditionally interacted with electro-mechanical devices and learned hands-on approaches to controls for engineering applications. Over several years the class theme has become focused on aspirational ethics. One manifestation of the ethics theme is assistive technology, where students complete an open-ended class project that must result in a device that will improve or assist people.

An important goal for the new laboratory module was to encourage students to take this idea of aspirational ethics and struggle with possible consequences of engineering decisions. The module replaced a more traditional controls module that had no back story and provided only technical knowledge. The new module uses the idea of a breathing assist lung to help students learn programmable logic controllers, but also to help them consider important ethical decisions.

Background

There are many challenges to addressing ethics comprehensively in engineering programs. Walczak et al. and Fleischmann provides an outline of many of the challenges and both suggest possible strategies for improving curriculum [5], [6]. An overview of strategies from several institutions is provided by Colby and Sullivan [7]. Most of the authors agree that integrating ethics through the full engineering curriculum is important for students to develop the best moral reasoning [8].

Hosapple et al. observed that many engineering programs introduce ethics using a “right and wrong” approach that is lacking the complexity needed for good ethical reasoning in engineers [9]. One aim of this study is to allow students to grapple directly with a subtle engineering application with ethical undertones.

Other research teams have investigated applied ethics in laboratory classes. Martin et al. used specific learning frameworks to introduce ethics to bioengineering students [10]. Del Carlo and Bodner found that students perceive ethics in a laboratory class very differently than they perceive ethics in real-world laboratories [11].

Course Design

While the course maintains the technical aspects of learning modern engineering tools and techniques, the emphasis of the role of the engineer and ethics has been accentuated in the discussions related to these technologies.

Approximately sixty percent of the course is dedicated to learning skills. The remaining forty percent is for completing project work. Student projects are framed with the understanding that engineering is in service to humanity, and students are required to identify, design, and prototype a device that can assist humans with needs. We spend time in lab discussing previous successful projects and students are prompted to submit three project ideas as individuals. Groups are then formed and teams select a "best" project and present their idea to the class. Through iteration and feedback, students refine their project proposal and are able to dedicate the rest of the course to its completion. Often these projects require additional learning, and this is an expected portion of the work.

Just a few examples of successful projects include:

- A modified walker that can sense and adjust to the height of stairs. This project idea was developed by students that had observed challenges with stairs for a grandparent who used a walker.
- A voice activated hospital bed. This student had spent time with a loved one in a hospital setting who often had to wait for a nurse to come and reposition the bed.
- An automatic transmission for a bicycle that helped people. Students in this team were inspired by a cyclist who had lost their right arm from the elbow down. While some shifting can be done with one hand, this particular solution was exciting as it was both technically challenging and provided assistance to many individuals.

In the course of the project students have an opportunity to consider the role of engineering and how devices may interact with people. One student after completion of the course observed, "I appreciated the component of the lab that was geared towards helping people, because for one of the first times in our college classes, we were able to see how a degree in mechanical engineering can be used in the real world. I enjoyed using LabVIEW and PLC in conjunction to make a system that could very well improve some else' life."

Experiment Design – New Lung Module

The lung module is an experimental exercise developed to help facilitate inspiration within students on how certain tools could be applied to in real-world applications. The module was created to address several specific learning objectives determined by the faculty team using backward design.

- Base competence with motion controllers and Programmable Logic Controllers (PLCs), including the use of timers, sensors, and actuators.
- Familiarity with modern engineering tools
- The ability to communicate through written and oral means in a professionally acceptable format the ideas associated with this course.

The module is an air cylinder lab that exposes students to programmable logic controllers (PLCs) and how to program using ladder logic. Students use RSLogix 500 to program the PLCs. The air cylinder is actuated with pressurized air through a solenoid, and equipped with position sensors which indicate if the piston is retracted or extended. When the final program is executed by students the air cylinder extended and remained extended for a set time before retracting, the process was then repeated for a fixed number of iterations.

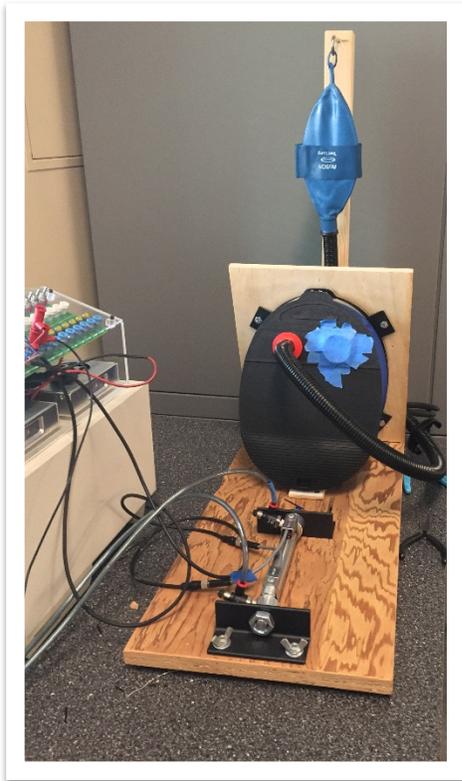


Figure 1. Lung module prototype connected to a PLC

In the new module, the students create a program to facilitate movement of the piston as a respirator. When the piston extends, it inflates a membrane representing a human lung. As the piston retracts the membrane will respond in a similar way. The idea is not to model an exact replica of a human lung, but instead simplify the idea of an artificial lung to show that students design a program that simulates a human lung or a simplified ventilator, seen in Figure 1.

The lung module was designed to provide a new viewpoint for students looking at hardware to be used with PLC's. The module inspires students with the idea that it is possible to make an impact that functions to benefit the medical field, and further benefit larger groups of people. It also helps them think about common engineering devices that are assistive in nature.

The lung module was also designed to serve as an example of aspirational ethics, where students focus not just on the rules and restrictions that traditionally define ethical behavior and, instead, think about what they can and should do with their engineering tools. It encourages students to consider that when designing engineering products, they must keep in mind, that their calculation accuracy can affect the lives of others. The instructor and teaching assistants discuss possible

outcomes like device failure, incorrect calculations, and the outcomes for the user of the device. The discussion is readily extended to consider other possible applications.

The lung module allows students to measure continuous position data of the piston tip and the fully inflated/deflated lung. A linear transducer is used to track continuous position data of the piston tip. Students can use the data to calculate velocity and acceleration. Table A-1 details the component list that comprise the lung module, excluded from the module are the PLC and air cylinder, along with the associated parts.

Table 1. Summary of components and costs associated with the new lung module. Existing piston module parts were also used.

| Component | Part Number/Serial Number | Cost per module |
|-------------------|---------------------------|-----------------|
| Membrane | 76-78176AP | \$30.29 |
| Pump | 68610E | \$14.08 |
| Proximity Sensors | TD590MD50 | \$129.00 |
| | | |
| Total | | \$173.37 |

Survey Assessment

To assess how student’s perceived the experimental module outcomes a survey was administered to students in the Fall of 2016 at the end of the semester. 66 students completed the survey in several sections with a total of 78 students enrolled, representing an 85% response rate. A portion of the student experienced the more traditional PLC laboratory and around half of the class used the new lung module.

The survey asked the students to rank how they perceived each laboratory module in the course. To allow comparison, students were asked to evaluate all the laboratory modules in the course, although the focus was on the new lung module and the assistive aspects of the course. An example question from the survey is shown below.

1. Rank the following laboratory experiments based on how much control you had over the laboratory experiment success (how open-ended was the lab)?

| Laboratory Module | How much control did you have over the laboratory experiment success? Circle one. | | | | |
|---|---|---|---|---|-------------------------|
| | Very little control | | | | A great deal of control |
| Programmable Logic Controller or Lung Module | 1 | 2 | 3 | 4 | 5 |
| LabVIEW | 1 | 2 | 3 | 4 | 5 |
| Motion Controller | 1 | 2 | 3 | 4 | 5 |
| PID Control with Matlab | 1 | 2 | 3 | 4 | 5 |
| Assistive Technology Project | 1 | 2 | 3 | 4 | 5 |

The results from this question are shown in Figure 3. Students reported feeling a great deal of control over most of the laboratory modules in the class. The average Likert score for all the laboratory modules was 3.92 with a strong distribution of a great deal for most of the lab modules, particularly the assistive technology project. There was no significant difference between the traditional PLC and lung module average rankings, both near 4.1.

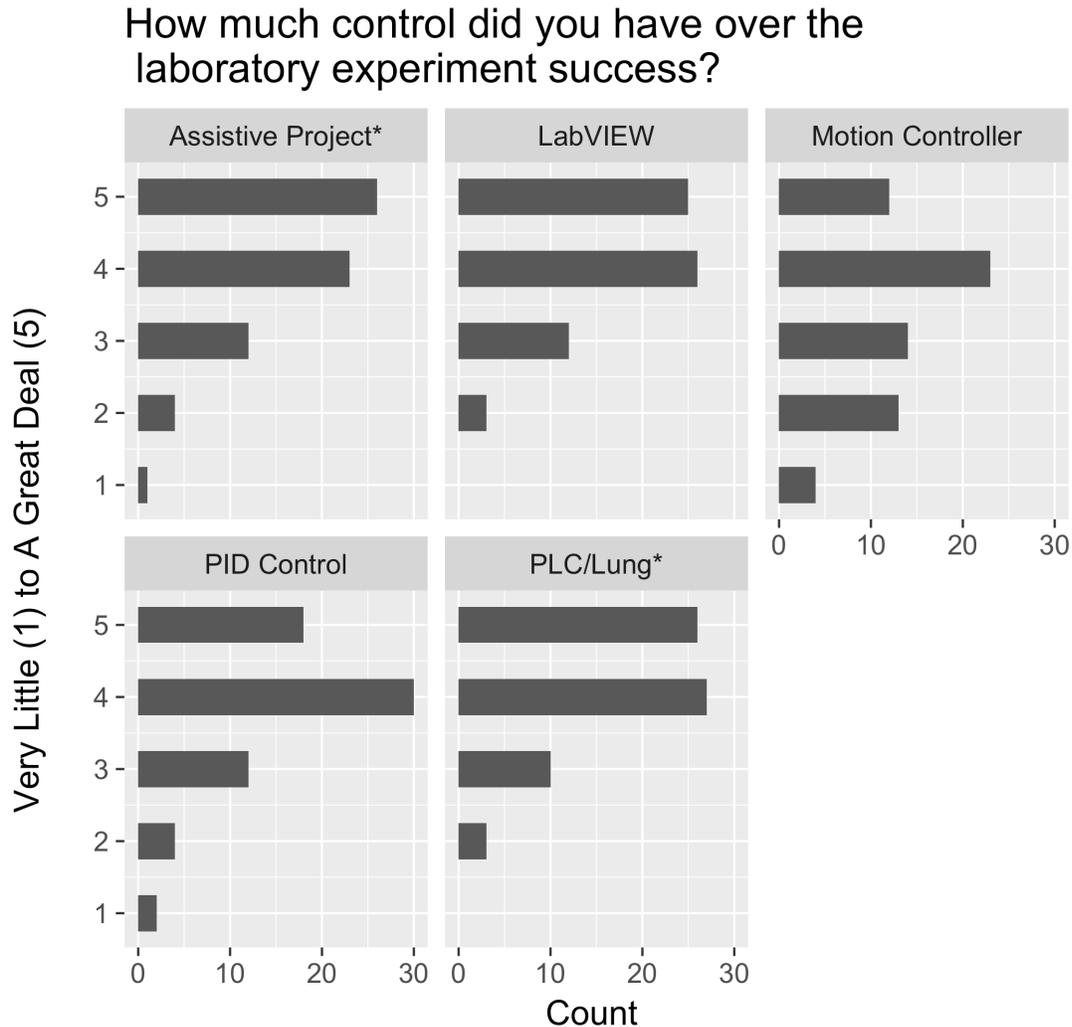


Figure 3. The student responses to the question, “How much control did you have over the laboratory experiment success?” separated based on laboratory module. The lung module was modified as part of the pedagogical ethics project and a portion of the students worked with the new module.

The students were also asked how invested they felt in each laboratory module. The overall average was 3.90, indicating the students felt very invested in all the lab modules in general. A summary of the responses by module is shown in Figure 4. In this case the PLC/Lung module performed well, but no significant difference was recorded for students that attempted the new lung module, both averages near 4.1.

How invested did you feel about learning the laboratory material?

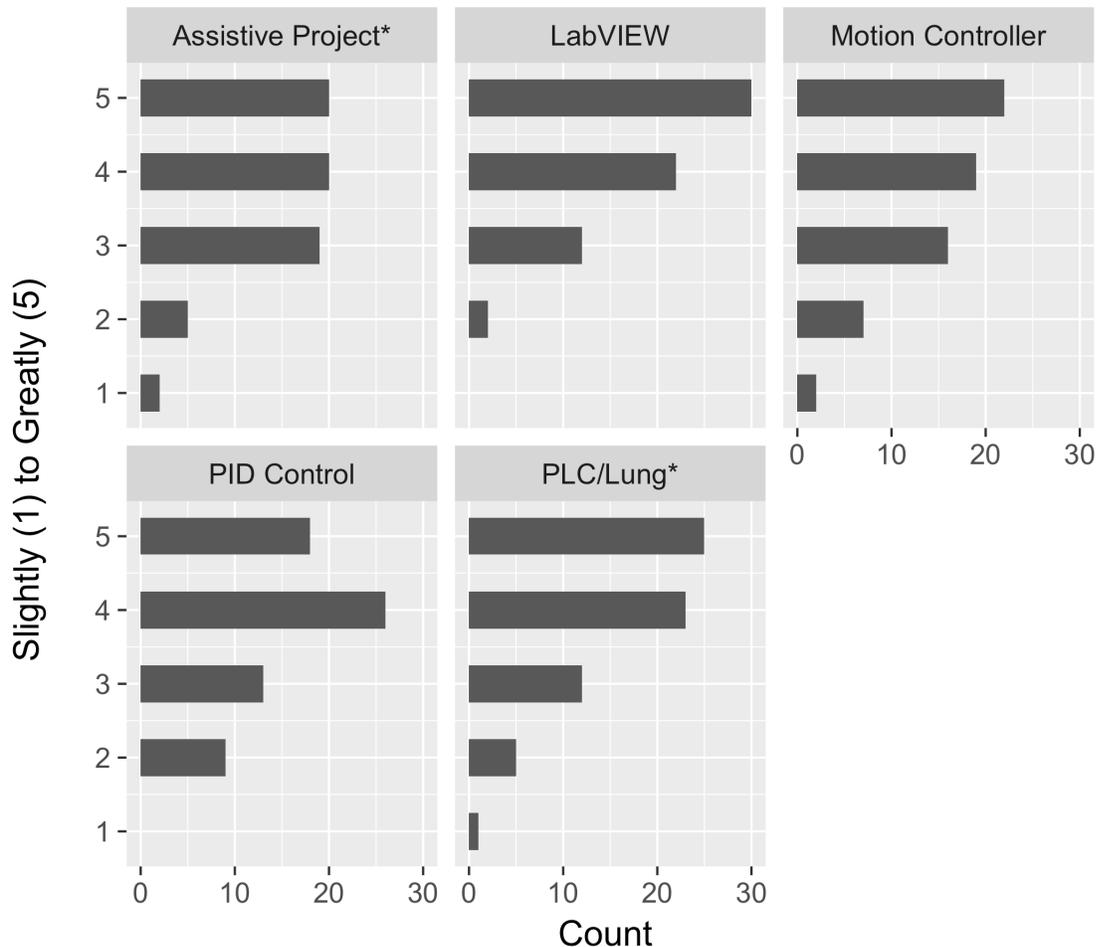


Figure 4. The student responses to the question, “How invested did you feel about learning the laboratory material?” separated based on laboratory module. The PLC\Lung module was modified as part of the project.

The students were then asked how competent they felt on each of the laboratory objectives that had been targeted by the design. Students reported strong confidence levels on all the learning objectives as shown by Figure 5, with an average of 3.84. Students also overwhelmingly (96%) indicated their competence had increased as part of the laboratory class.

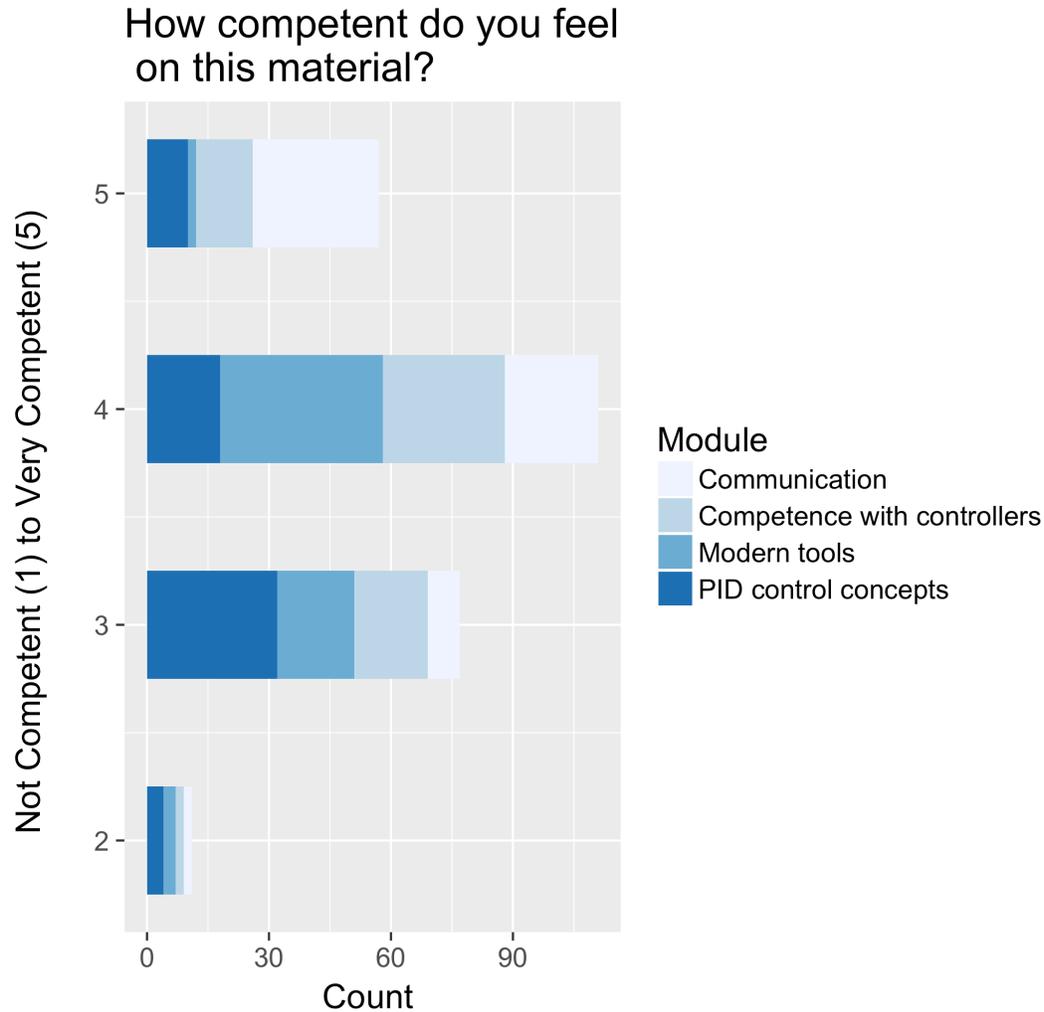


Figure 5. The student responses to the question, “How competent do you feel on this material?” separated based on the different learning objectives targeted by the project.

The last survey question focused on the way the lung module had influenced thinking about ethics issues. Students were asked to rate how the PLC module had helped them “appreciate how engineers are ethically charged to produce quality work” and “appreciate the role of engineering in service to humanity”. Since about half the students used the traditional PLC module and half used the new PLC lung module the responses were separated based on experience.

Figure 6 shows the responses to how the module helped students learn the technical skills associated with PLCs. The new and old modules were both strong, with the traditional PLC module averaging 4.26 and the lung module averaging 4.47.

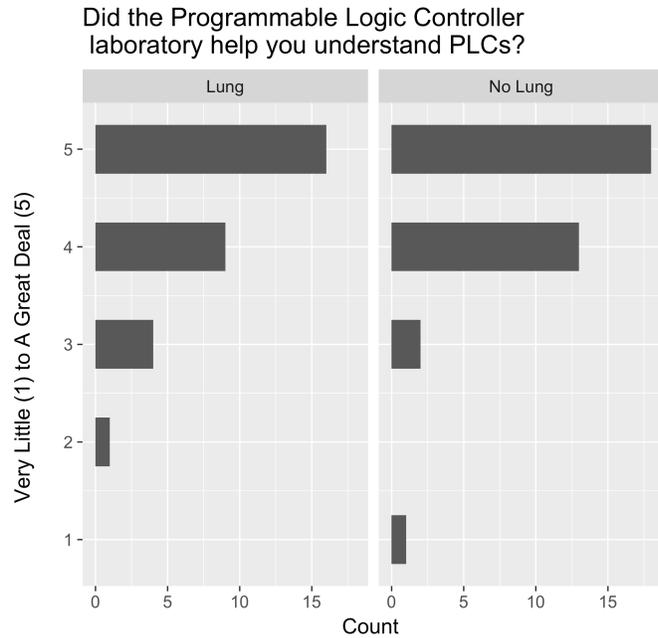


Figure 6. The student responses to the question about how much they had learned in different areas for the lung module. Responses are separated based on the different facets of the project.

Figure 7 shows the responses for how the old and new PLC modules impacted thinking about engineering as a service to humanity. The traditional module average was lower again with an average of 3.53. The new lung module was higher with an average of 3.90.

Figure 8 shows the student responses to how the PLC modules taught them about the ethical charge engineers have to do high quality work. The traditional module average was 3.24, lower than most of the other questions and the new module. The modified lung module had an average of 3.90, much higher than the prior module.

Did the Programmable Logic Controller laboratory help you appreciate the role of engineers in service to humanity?

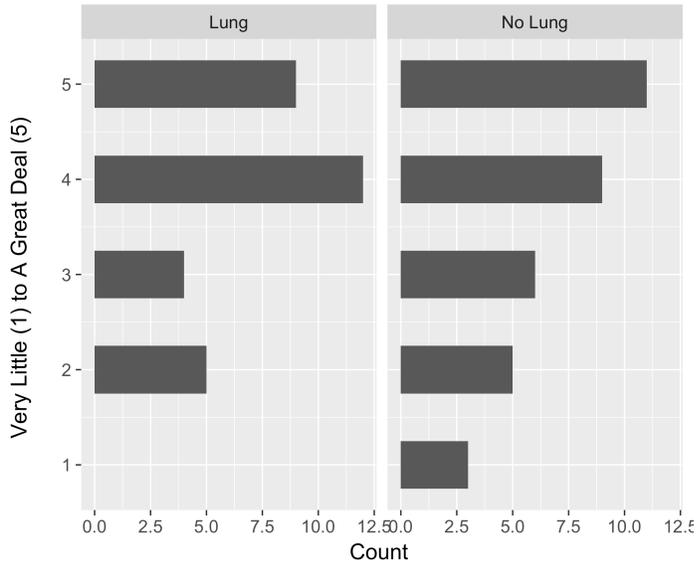


Figure 7. The student responses to the question about how much they had learned in different areas for the lung module. Responses are separated based on the different facets of the project.

Did the Programmable Logic Controller laboratory help you appreciate how engineers are ethically charged to produce quality work?

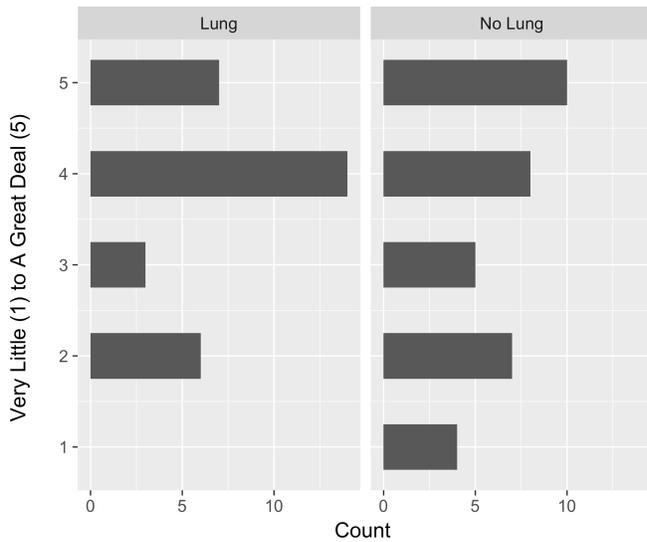


Figure 8. The student responses to the question about how much they had learned in different areas for the lung module. Responses are separated based on the different facets of the project.

Conclusions

A mechanical engineering laboratory course has evolved over several years to focus on service and ethics in the engineering profession. In 2016 a new laboratory module was designed for the course to encourage students to wrestle with ethical questions in the context of engineering technical work. The module was developed as part of a larger pedagogical effort using backward design across the full curriculum. The ethics implementation is also part of a curriculum-wide effort to expose students to the broad facets of engineering ethics through courses.

The new laboratory module was implemented as a low cost addition to the laboratory course. Students reported the new lung module significantly enhanced understanding of an engineering charge for ethical behaviors. They also reported that the module helped them understand how engineers could be of service. They reported even stronger success at learning the technical concepts of PLCs.

Future work will focus on enhancing other modules in the laboratory course and through the curriculum to introduce students to ethical complexity in engineering. This type of repeated exposure to ethics is important to help students develop into strong engineering professionals.

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