# Instrumentation Laboratory: Challenges of Teaching a Large Class

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Ms. Bernard is a graduate student of The University of New Mexico. As both a student and a teacher, she is a prime candidate to provide input that would improve the way engineering subjects are taught to students. By collaborating with other like-minded students and teachers, Ms. Bernard seeks to improve the quality of education that the students receive in a manner that positively affects more students.

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Keyword: instrumentation, engineering education, diagnostics, laboratory

Abstract

Regardless of the job description and duties, for every engineer, it is essential to understand how data is acquired and analyzed. Therefore, the implementation of an instrumentation laboratory in an undergraduate Mechanical Engineering curriculum is necessary. A laboratory specialized in instrumentation provides students with hands-on experiences – a component missing from many traditional courses, which focus mainly on theory. This course allows students to comprehend and apply the various methods and types of diagnostics that are used to collect data in numerous mechanical systems. The main challenge in an instrumentation laboratory at large engineering institutions is the class size. Most often, the amount of hands-on experience that each student receives decreases as the class size increases. Courses, such as this, are facing issues that arise from large increases in student enrollment. The main concern is how to continue to effectively educate students so that they learn essential skills with limited equipment and funds. Several teaching methods and techniques have been implemented in an undergraduate instrumentations laboratory course to address these issues. Some of these improvements include creating multiple small classroom environments, modifying the laboratory experiments to allow all students to gain hands-on experience, and encouraging students to work together. Students have responded positively to these changes and stated that these new techniques have improved their understanding of the material. Improved lab report grades corroborate student feedback. This paper will discuss these techniques and improvements that were implemented to successfully teach different instrumentation techniques to undergraduate Mechanical Engineering students in a large (100 students) class environment while retaining the hands-on approach.

## Introduction

Globalization has changed the economies of many nations. Many corporations now have a footprint in multiple countries and have a large base of talent to recruit from. A combination of globalization, economic conditions, and other factors has lead to increased competition for jobs of every discipline. It is for this reason that educational institutions need to adapt to changing demands if they are to prepare their students for what will be expected of them as they begin their professional careers. At the undergraduate level, laboratory courses are often where new technology and teaching methods are integrated into the curriculum. However, since the 1970s, many institutions have decreased the quantity or consolidated laboratory courses offered in an effort to curb increasing costs. A shift in the focus of faculty towards research combined with shrinking department budgets and the high cost of new laboratory equipment has left many laboratory courses outdated and understaffed.[1] Non-traditional teaching methods such as Problem-Based Learning (PBL) provide a way for instructors to give students the hands-on skills that they need and develop their critical thinking skills while working within the financial constraints placed on most courses. PBL is grounded in the idea that students should be facilitated by instructors in self-directed experiments that encourage critical thinking and problem solving amongst peers. It has been seen that PBL is an effective method to engage students with the fundamental engineering concepts being taught while also fostering collaboration amongst students to learn the intricacies of applying their knowledge to a real-world application.[2] Although it was seen by Cline and Powers that in order to fully realize the benefits of PBL, students and faculty must accept a larger work load. The entire teaching method taught must be restructured in a manner that the students are responsible for their empirical progression through the lab.[3]

This paper will discuss the restructuring of the curriculum of an Instrumentation Laboratory for undergraduate Mechanical Engineering students at the University of New Mexico. Increasing undergraduate enrollment during an economic downturn left the Instrumentation Laboratory poorly equipped to sufficiently fulfill the needs of its students. Feedback from students who recently completed the course was analyzed to identify areas that needed improvement. As a result of student feedback, a thorough restructuring of the curriculum was initiated. Short-term and long-term goals were established to improve the effectiveness of instruction in the laboratory. Short-term goals included implementing new technology and aspects of PBL into the curriculum. This was achieved by restructuring the lab from a “demonstration” format to a “facilitated hands-on” approach and by purchasing more equipment to accommodate increasing enrollment. Students were also paired into groups to perform the laboratory experiment and conduct the post-lab analysis. Long-term goals include the complete implementation of PBL into the curriculum, introducing new laboratory experiment, and securing funds to periodically purchase new diagnostic equipment as technology evolves. Changes to the curriculum to achieve the short-term goals have already been implemented into the course and strides are being made to work toward the long-term goals.

## Overview of Prior Curriculum

The curriculum taught in prior years consisted of a multitude of laboratory experiments that concentrated on various diagnostic tools such as operational-amplifiers, strain gauges, optics/polarization, and pitot probes. Since the Fall of 2009, student enrollment has grown from 42 students to 92 students enrolled in the Spring of 2014. Over the years, instrumentation equipment has progressively improved as well as increased in cost. Due to cost restraints and to keep up with technologic advancements, only one set of equipment is available for the students. Because of the large class size and the shortage of lab equipment, the laboratory experiments were conducted in front of the class only allowing a handful of students to volunteer. Therefore, these lab experiments simply became demonstrations for many students. The rapid increase in student enrollment and the quick technological advancements have hindered the course’s ability to give students the adequate knowledge and skills needed as an engineer.

## Problems and Issues with the Prior Curriculum

Teaching the essential knowledge and skills to approximately a hundred students in an instrumentation laboratory is very challenging. The large class sizes have forced the laboratory to be taught as a series of demonstrations rather than a series of lab experiments. Because of this many of the intended skills and applied knowledge that was once taught to the students of this class was no longer being disseminated. The curriculum could no longer ensure that all students could receive the hands-on skills that this lab intended to provide. These issues with the prior curriculum relegated the students to being observers rather than experimentalists. As a result, students did not gain problem solving, trouble shooting and critical thinking skills that are beneficial to engineers in the workforce and research environments.

## Course Techniques and Improvements

The new lab curriculum focuses on electrical, mechanical, hydrodynamic, and hydrostatic measurements. The lab experiments incorporate diagnostic methods to obtain voltage outputs, stress/strain, and pressure measurements. To address the issues that arose from the increase of enrollment and shortage of lab equipment, several improvements have been implemented to the Spring 2014 lab course. These improvements include variations in the structure of the course. The first implementation is to create the small group atmosphere. The lab sections were then separated into two smaller sections (approximately 12 students). Within these sections, groups of 2-3 students are assigned. Since the total lab time is cut in half, the lab experiments are condensed ensuring that the main objectives of each lab are achieved. Several samples of the lab manuals can be found on the website (See Appendix A). By condensing the experiments and dividing the students into small groups allows each group of 2-3 students to conduct each experiment. As a result the students are forced to get hands-on skills and learn the instrumental tools taught. The old curriculum focuses on the various diagnostic tools. The new curriculum implemented not only introduces these tools but also how these tools can be implemented in experiments to measure various diagnostics.

## Results

A mid-semester evaluation questionnaire was given to the students in the Spring 2014 Instrumentation Lab Course. This evaluation examined the students' opinions about the implementations and improvements in the laboratory. The feedback received is compared to the data retrieved from the Teaching Evaluations filled out by the students from the previous semesters.

By allowing each student to physically perform each lab experiment they gain skills such as becoming familiar with the hardware, problem solving, trouble shooting, and critical thinking. These are critical skills that are sought after by many employers. The new teaching methods provide students with guidance however each group is expected to run each experiment on their own. This self-led method encourages students to collaborate amongst themselves to solve and trouble shoot any problems they run into. According to past evaluations 50% of students in 2010 reported that they made exceptional progress in developing specific skills, competencies, and points of view needed by professionals. Comparing this percentage with the evaluation from Spring 2014, 81% of students feel a large increase in skill development that will benefit them in the workforce. Figure 2 shows the increase in skill development from 2009 to 2014.

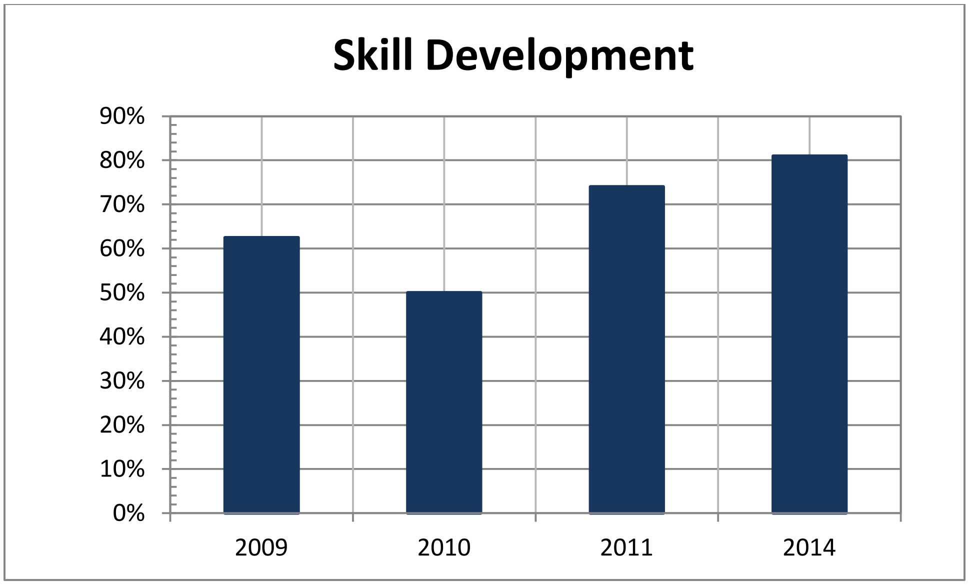


Figure 2. Student skill development for the years 2009 to 2014

The main objective in laboratory based courses in engineering curriculums is to teach students how the theoretical concepts learned in a traditional classroom environment are applied to real life engineering problems. In an instrumentation course, it is important that students understand the capabilities of various diagnostic methods and their limitations. The goal is to familiarize the students with these tools so when they go out to the work force they are knowledgeable about which types of diagnostics can be used to collect specific data along with an understanding of how to implement these measurement methods. Seventy four percent of students recognized that conducting each experiment has aided in their understanding of the theory and background of material they learned in other engineering classes. One student expressed, "I feel that this lab course has helped me to get a better idea of what circuits/ electrical components actually look like." To give each student the opportunity to get familiar with electrical circuits multiple breadboards, resistors, operational-amplifiers, and capacitors were purchases so each group had the ability to build various circuits from given schematics. As an outcome students learned how to read and wire electrical schematics. They also gained knowledge on how to use an oscilloscope to measure the voltage outputs. This course has also helps students visualize abstract concepts that they learn in solid and fluid mechanics.

Several studies have proven that working in groups have enhanced students' knowledge and professional development skills.[3, 4] In accordance to this finding the students were assigned partners whom they were expected to conduct the experiment and present their findings in a formal lab report. The basic idea of group collaboration and assignments is that students will learn from each other. This allows students to improve their teaching skills as they are constantly exchanging thoughts and opinions on each concept. Students are then forced to fully understand concepts to defend their hypothesis to their lab partner. A student expressed that "it is very helpful to have someone to ask questions and look over report material. It is helpful to be able to build on each other's thoughts, ideas, and material. Especially in today's technical world, sharing information, data, and working in groups is easier and more common than ever." A significant increase in lab report grades have increased between the Spring of 2014 and the Spring of 2013.

The average grade on the first lab report in 2013 was a F+ (58%) whereas in Spring 2014 this average jumped by 31% to a B+ (89%). In the mid-semester evaluations for the Spring 2014 course, 98% of students noted that working in a group has contributed to their understanding of the course material. Engineers in the workforce are constantly working with others on various projects. Another student explains that working in a group motivates students to stay on top of their work load as well as encourages them to produce higher quality work. This student states, “Working in a group allows me to work harder to guarantee that I do not let my partners down.” This accountability not only improves the students’ work ethic but also improves the way they interact with their peers. By exposing teamwork early in student engineering development they gain a sense of professionalism that is greatly beneficial in their future careers. Figure 3 illustrates the trend of the percentage of students who has expressed a substantial or exceptional progress in team working skills obtained during this course. Note the data from 2014 was retrieved from the mid-semester evaluation. The total percentage decreases by 25% from 2009 to 2010 where it then plateaus at 50%. In 2014 the total percentage of students who gained team working skills increases to 88%.

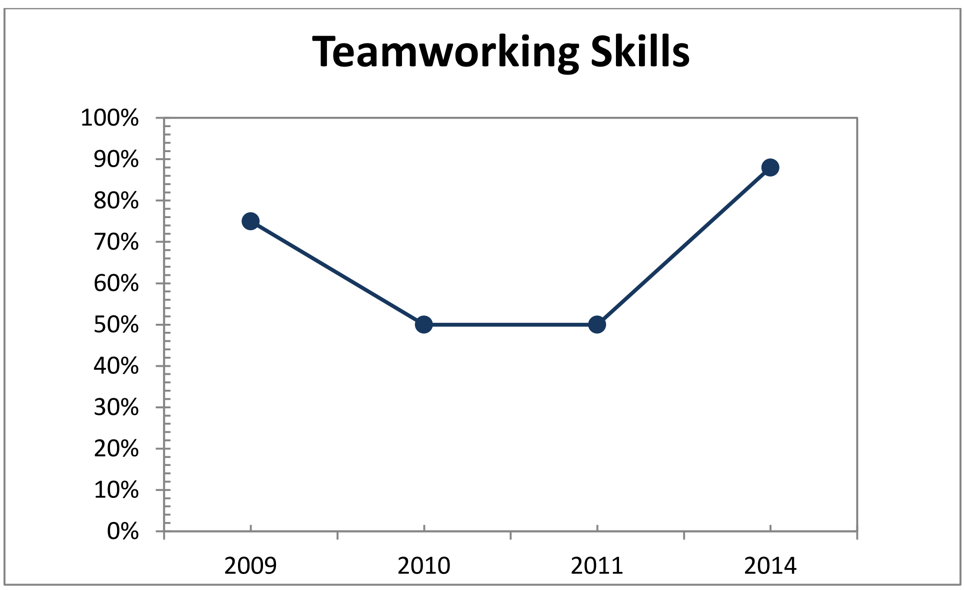


Figure 3. Student improvement of team working skills for the years 2009-2014

Not only is it important to learn how to implement these diagnostic tools but also to learn how to professionally present the obtained data in a written document. Therefore another large portion of the curriculum is group lab reports. Each group is required to submit a lab report for each experiment. The writing standards enforced in this course teaches the students how to formally present their data and cite references. The ability to effectively explain research and technical information to a general audience is very valuable to an engineer. The new curriculum places more emphasizes on writing formal reports and how to correctly present technical data. Student feedback shows that this emphasis has improved and given students more confidents in their writing skills. One student wrote, “I have never written a report like the ones we have been submitting before. I have finally learned the proper writing skills needed as an engineer. This class has taught me to work on assignments in advance rather than working on things at the least possible moment. With these reports however, I have learned to pace myself.” These skills will only improve as these students continue their engineering education and ultimately when they begin their careers.

## Conclusions

Over the past few years the enrollment in the Mechanical Engineering Department at the University of New Mexico has drastically increased. Teaching challenges arose in laboratory courses such as the Instrumentation Laboratory. The large class sizes and limited laboratory equipment posed issues in the teaching curriculum. Essential skills such as problem solving, critical thinking, and troubleshooting were no longer being taught to students because the labs transformed to a demonstration and lacked the opportunity for students to gain hands-on experience. To overcome this problem new teaching techniques were implemented in the course curriculum to increase student involvement in the experiments and provide them with more opportunities to gain hands-on skills. These changes ultimately allowed students to obtain the knowledge and skills that were originally intended to be taught by this course. Small group environments were created by dividing the lab course into many smaller sections. Lab experiments were condensed to allow each group of two students to perform each experiment. These implementations force students to collaborate amongst themselves and together overcome issues that they face during the experiments. Increasing the amount of hands-on experience received by each student while working with various diagnostic tools and equipment allows them to gain a better understanding of how these tools work. As an end result students become more comfortable using the equipment. Student feedback from a mid-semester evaluation has proven that these implementations have increased students' hands-on, writing, and team working skills. The increase in average grades has shown that the students are gaining a better understanding of the overall material that is taught in the course.

Although the teaching techniques that were applied to the Spring 2014 course have shown improvements, other recommendations are being considered for future classes. These recommendations include implementing laboratory experiments formed by students. Several students have expressed an interest in learning how to formulate a well thought-out experiment. This would include each group developing their own unique lab using one of the various diagnostic methods learned during the semester. They will carry out the experiment, collect the necessary data, perform the data analysis, and present their findings. This assignment will allow the students to experience the hardships of developing an organized and thorough experiment. They will also learn how to overcome the technical and analytical issues that they will face in the research/work environments.

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Appendix A

Sample lab manuals for several laboratory experiments that were implemented in this course can be found on the following link.

http://www.me.unm.edu/~kalmoth/me318_manuals.html