# Evaluating Course Effectiveness during the Transition from Demonstration to Hands-on Teaching Methods in the Solid Mechanics Laboratory

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The Mechanical Engineering (ME) Department at Mississippi State University is in the process of transitioning into a newly renovated Solid Mechanics Laboratory (SML), a senior level lab. Up until the Spring of 2018, SML procedures and experiments were performed mainly as demonstrations. The new lab will be focused on emphasizing hands-on procedures based on the format of the previously renovated Thermal Fluids Laboratory (TFL), also a senior level lab in ME. Equipment training is accomplished through instructional procedure videos accessed through Quick Response (QR) codes, a methodology presented previously by the authors at an ASEE-SE conference. After an introduction to the equipment through these videos, students complete lab experiments under the supervision of the lab instructor. Previous research performed in the TFL has shown that increasing student-equipment interaction enhances the understanding of different lab topics, as well as the student engagement. Therefore, the same principle has been implemented in the SML. The focus of this paper is to evaluate course effectiveness during the Fall 2018 semester of SML. This particular semester saw a mid-semester transition in the course's instructional strategy. The first three labs were run as demonstrations using equipment from the old lab. The last three labs were run emphasizing hands-on procedures using equipment from the new lab. This particular scenario offered the unique opportunity to receive feedback from one group of students experiencing both instructional formats during the same semester. Furthermore, this paper evaluates the course effectiveness by comparing how the two instructional formats apply to the newly revised ABET course outcomes (1-7). Surveys were administered to students after the first three-lab periods and the three periods of the hands-on format to evaluate the student response to the two instructional formats. The successful renovation and restructuring of the SML continues the department's initiative to improve the undergraduate ME curriculum and the results from this paper will be used to enhance the students' experience and will be implemented in other labs in our curriculum.

## Keywords

QR codes, laboratory instruction, interactive classroom, mechanical engineering labs, ABET outcome

## Introduction

The first stage of improving the classroom format of the laboratories in the Mechanical Engineering (ME) department at MSU was first discussed by Spayde et al. [1] in the 2016 ASEE-SE conference in Tuscaloosa, AL. Their paper discussed using Quick Response (QR) codes to give students access to supplemental information for the course such as instructional videos and lab handouts. In the following years, the QR system was expanded upon to be an integral part of the course. At the 2018 ASEE-SE conference in Daytona Beach, FL, Green et al. [2] discussed how QR codes now link students to a YouTube channel with instructional videos for each lab procedure. After watching these one to two minute videos, students have been trained enough to operate the lab equipment. This quick and simple training procedure opened the doors to change the format of the Thermal Fluids Laboratory (TFL) in the ME curriculum. The TFL is now divided into three rotations each covering a section of thermal sciences. Each rotation contains three different pieces of equipment that cover a topic within the section. On any particular lab day, all three pieces of equipment for the rotation run simultaneously, and over a course of three weeks, the student groups rotate among the three pieces. This methodology has increased the students' hands-on time with the equipment, and survey results have shown a positive response to this approach. Research shows that other educational institutions are shifting towards a hands-on approach in some of their courses to solidify concepts through concrete learning techniques[3–5].

The newly renovated Solid Mechanics Lab (SML) uses this rotation format as opposed to the demonstration style of previous semesters. Labs conducted in the demonstration style were run by an instructor who demonstrated the use of a piece of equipment for the entire class at once (24 students per section). The hands-on style labs are run in the same rotation format as the TFL. An aspect that this new lab presents is an emphasis on engineering standards, primarily from the American Society for Testing and Materials (ASTM). All of the lab procedures have associated ASTM standards, and throughout various lab assignments, students are required to refer to and adhere to these documents. The assignments in new SML are designed to make students take initiative in researching the methods for completing each lab procedure. In addition, the large emphasis on engineering standards leads to a large consideration of engineering ethics as opposed to assignments from previous semesters.

Throughout the recent renovations of the undergraduate laboratories in the ME Department, the labs have been evaluated for the success of each aspect of the renovation. The purpose of this most recent evaluation was to see if the hands-on format of the renovated TFL worked well in the SML and if a shift towards hands-on, self-guided learning helped the course to better fit within the new 1-7 ABET outcomes. Student survey responses and instructor course reviews were used to map out where the outcomes line up for both the demonstration and hands-on styles of SML. The student survey responses were also studied to see if they were a viable method for assessing the ability of a course to meet part of or an entire ABET outcome.

## Methodology

The first half of the Fall 2018 semester SML was run as the demonstration style using old equipment. The three labs included a demonstration of an impact drop tower test, a rotary bending fatigue test, and a mass spring damper system. The second half of the Fall 2018 semester of SML was run as the hands-on style using the new equipment. Three pieces of equipment were a part of a three lab rotation. The equipment included a Rockwell C Hardness test, a tensile test, and a bending test. Each piece of equipment had an associated procedure video located on the ME

Department YouTube channel (https://www.youtube.com/channel/UCXzv-JpFTw0I5PSNh_uUNaA) and accessible through a QR code on the lab handout.

A pre-lab assignment was assigned for each piece of equipment. Students were asked to detail the process for running the procedure including preparing the specimen and completing the data analysis. The assignment called for reference to an ASTM standard. The purpose of the pre-lab assignments was to give students experience with self-guided learning. When students got to the lab, the lab handouts had a procedure on them, but due to the pre-labs, the students were familiar with the procedure they were to complete. The procedures themselves were then an opportunity for the students to visualize the material they had already researched. This gave the SML assignments a larger focus on self-guided learning. Previously in the old lab, some of the post-lab assignments asked students to research the topic and draw conclusions of their data based on published results. The pre-labs of the new lab gave students an end goal and left determining how to reach said goal to the students.

As a continuation of the self-guided learning established in the pre-lab assignments, the lab procedures called for a step to be completed but only gave instructions to reference the standard for how to complete it. Students referenced the provided ASTM standards for various steps including: from the Rockwell C Hardness test, the minimum distance allowed between indentations; from the tension test, the rate at which the crosshead moves; and from the bending test, how to calculate the distance between the two support rollers. The use of engineering standards is an important part of accomplishing the ABET criteria for engineering curriculum[6], and therefore is strongly emphasized in the new SML.

Each lab (in both the demonstration and hands-on style) had a lab report assignment associated with it. The assignment gave various calculations to complete and topics to address and required student groups to write a full lab report on the procedure and results.

Both styles of labs also had a form of supplemental video for each procedure. The demonstration style labs had thorough videos that walked the students through the procedure so that all students could see the procedure completed up close. The hands-on style labs had the procedure videos intended to train the students to use the equipment. While not as thorough, these videos gave a general walkthrough of the procedures.

## Instructor Evaluation

Due to the applied nature of the SML, the course has the ability to cover some aspects of multiple ABET outcomes. The instructors of the undergraduate labs in the ME Department evaluated the new 1-7 ABET Outcomes and determined that numbers 3-7 were addressed to some extent in the SML. These outcomes are listed in Table 1.

## Table 1: ABET Outcomes Applicable to SML

| *Number* | *Outcome* |
|---|---|
| 3 | An ability to communicate effectively with a range of audiences |
| 4 | An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts |
| 5 | An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives |
| 6 | An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions |
| 7 | An ability to acquire and apply new knowledge as needed, using appropriate learning strategies |

While it is not expected that the SML will fully address any ABET outcome, the teamwork and self-guided learning present in the lab lend to encompassing the premise of the applicable outcomes of Table 1. It was noted that the pre-lab assignments and large focus on using standards in the new SML had the potential to allow the SML to better accomplish these outcomes.

## Student Response

For the student responses, two surveys were created. The first survey was administered after all three demonstration style labs were completed. The second survey was administered after the rotation of the hands-on style labs. Some of the questions were asked using the language of ABET Outcomes 3-7; however, no mention was given of ABET. Instead, the survey aimed to get an objective view from the students of the course’s effectiveness at achieving part of the chosen ABET outcomes. If the students believed that the lab was giving them the opportunity to accomplish the statements, then it followed that the course was accomplishing at least part of the ABET Outcomes to a certain degree of success. Table 2 list the questions from the first survey. The first three questions directly address the students’ ability for each piece of equipment, and the remaining eight questions address the labs as a whole.

**Table 2: Survey Questions Administered After the Three Demonstration Style Labs**

| *Question* | *Statement* |
|---|---|
| Q1 | I could run a drop tower test on my own. |
| Q2 | I could run a rotary bending test on my own. |
| Q3 | I could operate a mass-spring-damper system and an accompanying DAQ on my own. |
| Q4 | I could duplicate the procedures after watching the demonstrations. |
| Q5 | I could perform accurate data analysis for the experiments after watching the demonstrations. |
| Q6 | I relied on the supplemental demonstration videos for help with writing my lab reports. |
| Q7 | I believe the first three lab assignments have improved my ability to communicate effectively with a wide audience. |
| Q8 | I believe the first lab assignments have allowed me to practice working on a team where said team has a collaborative and inclusive environment, establishes goals, plans tasks, and meets objectives. |
| Q9 | I believe that the first three lab assignments have required me to acquire and apply new knowledge as needed. |
| Q10 | I believe the first three lab assignments have allowed me to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgement to draw conclusions. |
| Q11 | I believe the first three lab assignments have allowed me to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts. |

Table 3 lists the questions from the second survey. As with the first survey, the first three questions directly address the students' ability for each piece of equipment. The remaining eight questions address the labs at a whole, but the current data only provides results for one third of the desired results. Future work includes administering the second survey again at the conclusion of the three rotations in the hands-on style labs to have a better set of results.

**Table 3: Survey Questions Administered After the First Rotation of New Equipment**

| *Question* | *Statement* |
|---|---|
| Q1 | I could run a Rockwell Hardness test on my own. |
| Q2 | I could run a tensile test on my own. |
| Q3 | I could run a bending test on my own. |
| Q4 | I could duplicate the procedures I performed after completing the labs. |
| Q5 | I could perform accurate data analysis for the experiments I performed after completing the labs. |
| Q6 | I relied on the procedure videos for help with writing my lab reports. |
| Q7 | I believe the first rotation assignment has improved my ability to communicate effectively with a wide audience. |
| Q8 | I believe the rotation assignments have allowed me to practice working on a team where said team has a collaborative and inclusive environment, establishes goals, plans tasks, and meets objectives. |
| Q9 | I believe that the rotation assignments have required me to acquire and apply new knowledge as needed. |
| Q10 | I believe the rotation assignments have allowed me to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgement to draw conclusions. |
| Q11 | I believe the rotation assignments have allowed me to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts. |

All of the questions for both surveys had a 1-10 Likert scale response system. For Q1-Q3, the scales ranged from low ability to perfect ability. For Q4-Q11, the scales ranged from strongly disagree to strongly agree. It can be seen that while the wording was changed for Q4-Q11 for the two surveys to more accurately describe the lab assignments, the questions are assessing the same aspects of the assignments. A comparison of the results for Q4-Q11 for the two surveys is shown in Figure 1. The bars on the left correspond to the average response for the first survey, and the bars on the right correspond to the average response for the second survey.

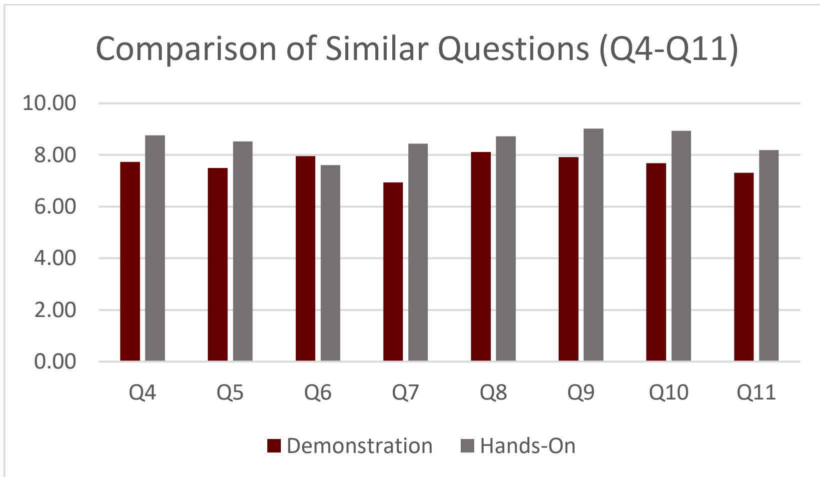


**Figure 1: Comparison of Q4-Q11 for Both Surveys**

In general, the results from Figure 1 show that the approach in the new lab is more beneficial to the students than the one applied in the old lab. Based on the students' responses and the overall course assessment, the instructors believe that the hands-on style lab is able to achieve aspects ABET Outcomes 3-7 better than the demonstration style lab. An increase in average response is seen for every question except Q6. However, the decline in average response for Q6 is positive because it means the students relied less on a supplemental video to write their lab reports (the most applicable section being the methodology). This is most likely due to the students completing the procedures themselves.

The results of Q6 are validated by the results of Q1-Q3. Figure 2 shows a comparison of the students' perceived ability to use the lab equipment. The values shown in Figure 2 are the average response for all of the pieces of equipment for each style of lab.

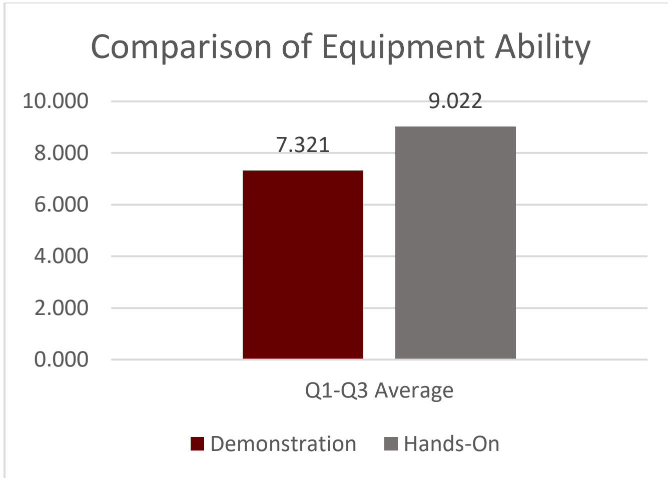


**Figure 2: Comparison of Equipment Ability**

Figure 2 shows that although the students were confident on their ability to operate the equipment with the demonstrations labs (old Lab), with the new format, hands-on style labs, their confidence level increased. As with Q6, this is most likely due to the fact that the students completed the procedures themselves in the hands-on style lab and as a result are more familiar with the equipment.

## Student Comments

In the second survey, students had the opportunity to provide comments about their lab experience. Below are select responses from these comments:

- *"The new lab format allowed me to actually learn what was taking place and allowed me to gain a better understanding for what was happening during the lab. I really appreciate the lab upgrade and the opportunity to use the new equipment."*
- *"It was a great semester! New SML is a blast!"*
- *"Lab was really enjoyable this semester."*
- *"The new lab format is a lot better than the old since we are able to physically run the experiments ourselves."*
- *"I like that the new lab allowed students to get hands on experience with the different equipment. The pre labs were a challenge to parse out and understand the relevant technical information from the standard, but was beneficial for becoming familiar with the test procedures and results analysis."*

These comments supplement the results of the Likert scale questions from the survey. Overall, students enjoyed the new lab format and found it more beneficial to their education

## Conclusions and Future Work

The survey results showed that the hands-on style labs conveyed the ABET Outcomes better than the demonstration style labs. These results confirmed the course assessment by the instructors. The results also showed that student response can be a useful tool when evaluating a course's effectiveness at accomplishing ABET outcomes. While they may not be familiar with ABET, the students' perceptions of the course can mirror the course's success at meeting parts of ABET outcomes. Therefore, the same approach and assessment used in the newly renovated SML will be used when renovating and improving future ME laboratories. Future labs will be designed with a strong focus on hands-on procedures. The SML renovation will be complete in Spring 2019 when the entire semester is run with multiple rotations of hands-on procedures.

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