Use of Instructional Videos to Enhance the Learning Objectives of the Thermal Fluids Laboratory

Morgan K. Green, Dustin L. Spayde, and Pedro J. Mago
Department of Mechanical Engineering, Mississippi State University

Abstract

The Mechanical Engineering (ME) Department at Mississippi State University has recently renovated the Thermal Fluids Laboratory (TFL). In addition to adding new equipment, new instructional techniques have been implemented in the thermal-fluids laboratory course. One of these techniques is the use of Quick Response codes on each piece of equipment that demonstrates the experiment in a tutorial video hosted on a YouTube channel for the course. Due to the large enrollment in the ME department, multiple sections of the TFL have to be scheduled every semester. This innovative technique is designed to enhance students' learning experience, streamline course instruction to ensure consistency across multiple sections, and assist in meeting ABET course standardization requirements. Also, the implementation of this technique allows instructors to oversee multiple experiments at once while allowing different groups to get hands-on experience with their experiment, which is one of the critical components that need to be emphasized in the lab experience.

Keywords

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

Introduction

Since its introduction in 1994, the QR Code developed by DENSO has been widely used in industries such as manufacturing, warehousing, logistics, retailing, healthcare, life sciences, and transportation, among others. In recent years, with the growth in smartphone availability, QR codes have been used in applications for the general public such as airplane boarding passes, car buying, and mobile coupons, marketing, etc[1]. In addition to that, QR codes have been used in education at many different levels, from early stages to college level. Some of the most popular uses in education include worksheets with solutions access, videos of experiments or science projects, and links to lab safety procedure, among many other possibilities[2,3]. The use of QR codes has many advantages such as easy implementation, highly accessible and portable medium for instruction, creation of an interactive classroom environment, and providing students with an innovative perception of classroom techniques[4]. Rikala and Kankaanrata[5] presented a study on blending classroom teaching with QR codes and concluded that the use of QR codes in problems encouraged students to persevere with the problems which led to good learning outcomes. In a similar study, Chen et al.[6] adopted the QR codes together with mobile technology to deliver supplementary materials and questions to support paper-based reading activities for students. In another study, Rikala and Kankaanrata[7] reported that with QR codes, learning can be extended beyond the classroom, and learning materials are no longer limited to textbooks and could include videos, pictures, etc.

Another important aspect of any laboratory course is for the students to get the hands-on experience in the course. For some engineering students, it is difficult to link new concepts to physical problems, since the formulas associated with the new concepts make little sense to them[8]. For these situations, hands-on experiments can be an effective way to link the concepts with the physics. The importance of hands-on experience has been also reported by Zang et al.[9] Even though they focused on design projects, they emphasized that hands-on provide students with a valuable experience needed when looking for employment. The thermal-fluids lab in the ME department is an excellent course to emphasize the hands-on experience to solidify the thermodynamics, heat transfer, and fluids concepts that our students learned early in the curriculum.

In the current paper, the usefulness and implementation of QR Code in a thermal-fluids laboratory, senior-level mechanical engineering undergraduate laboratory course, is discussed. The Thermal Fluids Laboratory (TFL) at the ME department at MSU was recently renovated and QR codes have been installed in each piece of equipment to demonstrate a tutorial video of each of the experiments in the course. This idea was originally presented by Spayde et al.[10] in the 2016 ASEE-SE conference in Tuscaloosa, AL. Since then, new instructional videos have been developed and a YouTube channel has been created to host all the instructional videos for the course. All the videos were created in house and all of them specifically target the learning objectives of the students in the TFL. Due to the large enrollment in the ME department, approximately 940 undergraduate students, multiple sections of the TFL have to be scheduled every semester. Therefore, the technique presented in this paper is designed to enhance students' learning experience, streamline course instruction in a manner that ensures consistency across multiple sections, and assist in meeting ABET course standardization requirements. In addition, the implementation of this technique allows the instructor to oversee multiple experiments at once while allowing different groups to get hands-on experience with their experiment, which is a critical component that need to be emphasized in mechanical engineering curriculum.

Methodology

The TFL has recently undergone a total renovation in both facilities and equipment. The renovated space was first opened for student use in Fall 2016. However, the new lab format for TFL was implemented in Fall 2017. The lab equipment was divided into three segments: fluid mechanics, thermodynamics, and heat transfer. Each segment has three pieces of equipment that cover topics in the segment and was carried out over a span of three weeks. A stand-alone radiant heat lab is placed in between two of the segments. The labs were run on a rotation format. For each hour of lab, all three pieces of equipment were run. Three groups ran the equipment for the first half hour, and after they completed the experiments, the remaining three groups ran the equipment for the second half hour. In the second week of the segment, each group was rotated to different pieces of equipment so that each group used all of the equipment over the three week span. This new format gave students exposure to ten pieces of equipment.

Because of the independent work that arose from running three separate pieces of equipment, instructional videos were key to helping the students run the equipment properly. At the beginning of each lab, the groups were given their lab assignments and handouts for the day. Each handout contained a set of written instructions for the experiment, a series of post-lab objectives, and a QR code. After students received the handout for their assigned equipment, they scanned the QR code on their handout. This QR code sent the students to a video that walked them through the entire procedure for the experiment that was assigned to them. This technique helps students to get ready to use the equipment by themselves by getting familiar with the procedure and its terminology. One of the procedure QR codes for the Vapor Compression Cycle (VCC) experiment as well as the VCC equipment are shown in Figure 1.

(a) (b)

Figure 1. (a) Vapor Compression Cycle Equipment (b) Procedure QR Code for the Vapor Compression Cycle Experiment

Survey to Students

To evaluate the effectiveness of the implemented technique in the TFL, students were given an optional survey asking about their experiences in the lab during the Fall 2017 semester, and 65 students submitted responses. The questions are compiled in Table 1.

Questions 1 through 4 were used to assess the use of QR codes in the course. The same questions were asked in a previous survey given to TFL students during the Fall of 2015 for a previous study[10]. The 2015 survey preceded renovations to the TFL laboratory and equipment. The first question was originally designed to determine if students were using the QR content outside of lab to assist with post-lab work and warranted a yes/no response. The 2017 results for Question 1 are shown in Figure 2. As can be seen, 89% of respondents reported their group accessed the QR code content outside of the scheduled lab hours. While this is slightly down from the 2015 survey, the results still show that student groups overwhelmingly use this content as a resource after lab hours are over.

Table 1. Survey Questions Administered to the TFL students

Question	*Statement*
Q1	Has your group used the course's QR content outside of lab hours?
Q2	The QR code content has been helpful in understanding the lab equipment.
Q3	The QR content was helpful when writing my lab reports/completing post-lab questions.
Q4	I have a better understanding of how to operate lab equipment because of the QR code content.
Q5	I believe hands-on experience is an important component of my engineering education.
Q6	I had hands-on opportunities to use the lab equipment during the lab time.
Q7	The video instructions in this course were clear and informative.
Q8	The video instructions and hands-on approach in thermal-fluids lab has better prepared me than the demonstration approach of solid mechanics lab.
Q9	If you are currently taking or have taken the solid mechanics laboratory course, compare and discuss your experiences with the two courses.

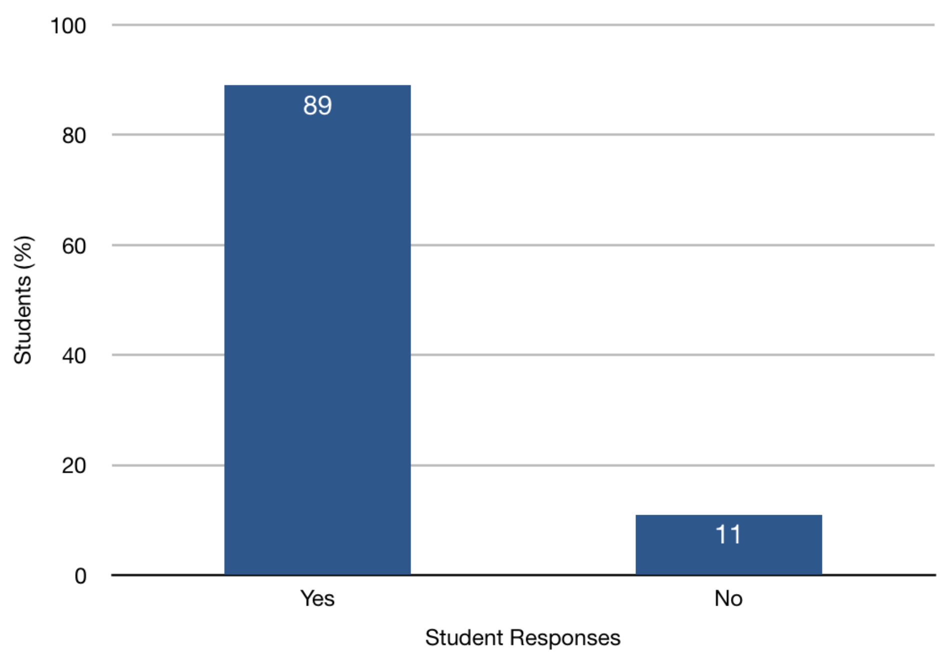

Figure 2. Q1 Responses

The remaining survey questions have a 1-5 Likert Scale responses, with 1 being "strongly disagree" and 5 being "strongly agree." The 2015 and 2017 responses for Questions 2-4 are compared in Figure 3. The improved responses in the students' ability to understand and operate the equipment (Q2 and Q4 seen in Figure 3) are a clear indication of the success of the QR codes and procedure videos implemented in Fall 2017. While still very positive, the average response for Question 3 went slightly down from 2015 to 2017. One reason for this drop may be due to a change in the QR content this semester. In 2015, the QR content included methods for answering post-lab questions, but in 2017 the QR content only included videos that walk through the experiment procedures. Therefore, the results are capturing two slightly different scenarios.

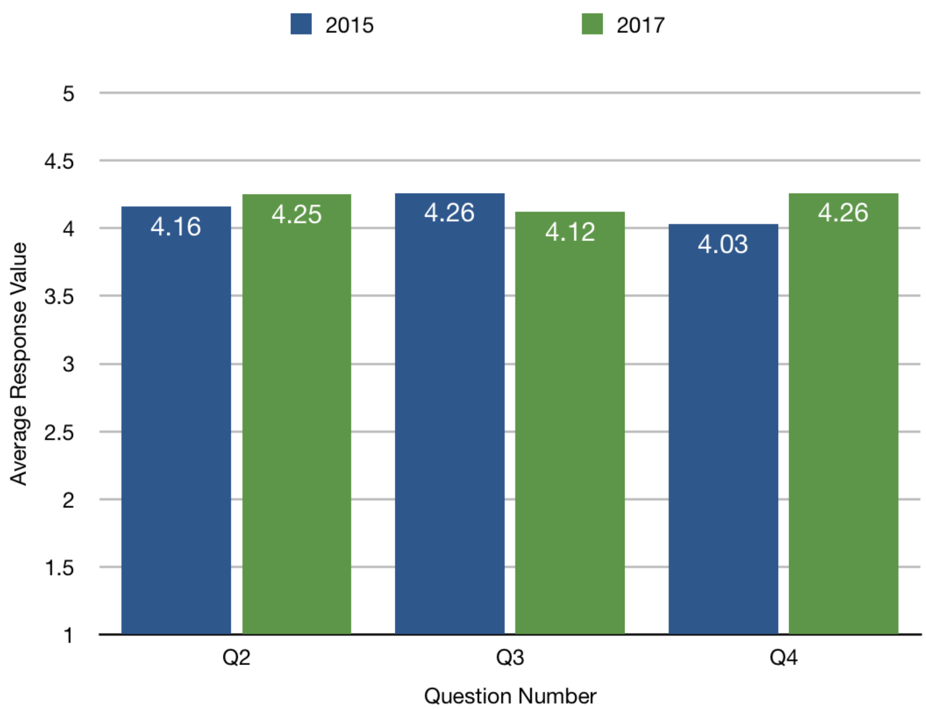

Figure 3. Q2-Q4 Responses for the 2015 and 2017 surveys

The remaining questions were asked to gauge the success of the new rotation format implemented in Fall 2017 and how it is improving the hands-on experience of the students. Specifically, the last two questions of the survey asked students to compare and contrast their experiences in the TFL and the Solid Mechanics Laboratory (SML) that is part of the mechanical engineering curriculum at MSU. The lab and equipment for SML has not yet been able to be renovated as of Fall 2017. Due to the nature of the equipment currently in the lab, SML Fall 2017 has a larger focus on experiments run in a demonstration format than TFL. The graduate teaching assistant ran those experiments while the students observed. Therefore, the SML procedures did not have a strong hands-on component like the procedures currently implemented in TFL. The responses for Questions 5 through 8 are shown in Figure 4.

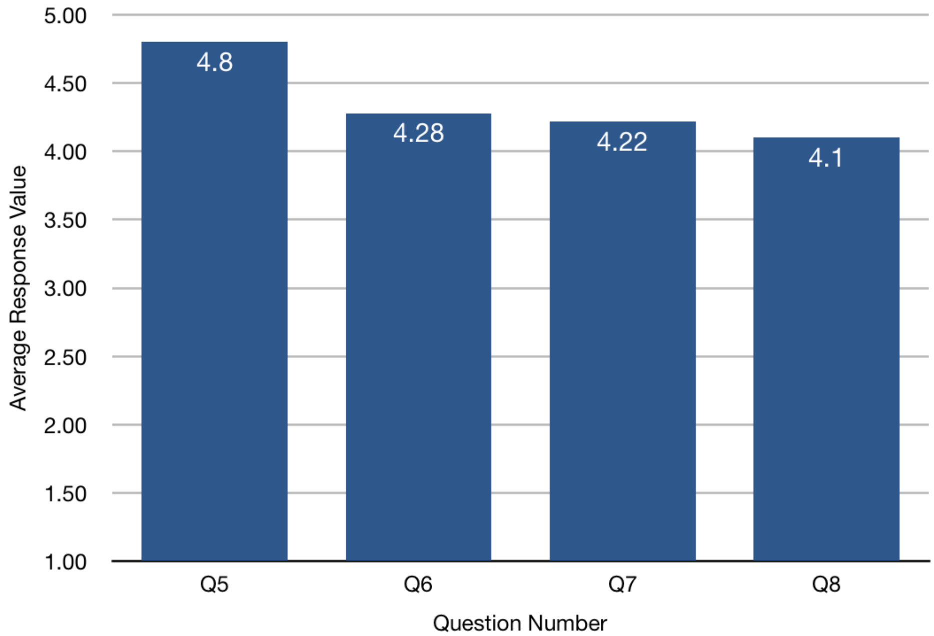

Figure 4. Q5-Q8 Responses

The information presented in Figure 4 shows positive feedback for the rotation format implemented in the Fall 2017. The majority of students either agree or strongly agree that the rotation format has given them hands-on experience and a better understanding of the different thermal fluid concepts. The average response value for Question 8 proves that students find the hands-on approach of TFL to be more informative and valuable than the demonstration approach used in some of the SML experiments. Finally, Question 9 gave the students an opportunity to provide comments on the new technique used in the TFL compared with the SML. Below are select responses showing a positive reaction to the technique implemented this semester and the hands-on experience in TFL:

- "TFL is more enjoyable because of the hands-on experience. The QR codes help gain a better understanding of the test that would otherwise be time consuming."
- "I feel better equipped to complete quality post lab assignments in thermal fluids lab than solid mechanics. The hands-on approach allows me to understand what is happening conceptually better than the demonstration approach."
- "I feel like I learned more in thermo fluids rather than solid mechanics. I think this is because the thermo labs were hands-on compared to the solid mechanics lab."
- "The TFL is more helpful because of the hands-on aspect that we do not have in SML."
- "Hands-on experience is very important in life and also for engineering. The Solids Lab needs to be structured and have the same level of technology as the Thermo-Fluids Lab."
- "It has been a lot bet being able to actually perform the labs to actually write the labs. Solid mechanics lab would be more helpful if we could actually operate the labs as in TFL."

Overall the answers from the students both confirm the positive impact of the rotation format of the lab and the hands-on experience that it provides in the TFL. Furthermore, the comments and positive feedback from this study help set the direction the mechanical engineering department will take moving forward with this type of courses.

Conclusions and Future Work

This paper presented the results to an implementation of a rotation format technique in the TFL in the ME Department at MSU. The rotation format was supplemented with QR codes that walked the students through the procedure for each piece of equipment. The rotation format of the labs was able to give students more hands-on experiences with a larger amount of equipment compared to the demonstration format used in some experiments in the Solid Mechanics Laboratory and the Thermal Fluids Laboratory prior to renovations. The results gathered from an administered survey to the students showed that the rotation format and the QR codes used in TFL help in covering topics effectively and ensuring that students understand the procedures and results, while providing them with hands-on experience in the course. While supplemental information is provided in PDF format to the students for all of the labs, future work includes integrating QR codes for supplemental information directly into the lab procedure handouts. These additional QR codes will consolidate the information physically given to students to one handout. In addition, the positive responses for the rotation format and hands-on experience provides the ME Department with valuable information that will be used during the renovation of the Solid Mechanics Laboratory. . In addition, this technique will help ensure instructional consistency when the TFL is taught at the MSU Gulf Coast Campus, a satellite campus of the ME department, in the Spring of 2018. As the QR codes and instructional videos are further integrated into the laboratories, the content of the videos will be assessed and any refinements will be made to improve the students' educational experience.

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Morgan K. Green

Morgan Green is a master's student in the Mechanical Engineering Department at Mississippi State University. She obtained her B.S. in Mechanical Engineering from Mississippi State University in 2017. Her graduate work is centered around engineering education, both in the K-12 division and at the undergraduate level.

Dustin L. Spayde

Dustin Spayde is an instructor in the Mechanical Engineering Department at Mississippi State University. He obtained his M.S. in Mechanical Engineering from Mississippi State University in 2013. He has a high interest in undergraduate education and focuses on laboratory based curriculum courses.

Pedro J. Mago

Pedro J. Mago is Department Head and PACCAR Chair Professor for the Mechanical Engineering Department at Mississippi State University. He teaches undergraduate courses in thermodynamics, air conditioning, power generation systems as well as graduate courses in advanced heat transfer. Dr. Mago is the author of more than 150 archival journal articles and conference papers.