Integration of Interactive Print Media into Thermal Fluids Laboratory Equipment to Aid in Laboratory Instruction

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Abstract

The Mechanical Engineering (ME) Department at Mississippi State University is in the process of renovating the Thermal Fluids Laboratory equipment and instructional techniques. This renovation includes the implementation of interactive print media, such as Quick Response (QR) codes, that incorporate smartphone applications to access laboratory equipment operational instructions, video tutorials, and more. The purposes of this integration are to enhance students' learning experience and to streamline course instruction in a manner that ensures consistency across multiple sections. Additionally, it will facilitate students' engagement by providing them with greater accessibility to lab operational practices, increasing student development of independent-learning strategies, and allowing them to take advantage of modern technology in the classroom. After successfully implementing these techniques in the laboratory environment, the department plans to extend this initiative to enhance other courses in the ME curriculum. Overall, feedback from students about the use of QR codes in Thermal Fluids Laboratory has been overwhelmingly positive.

Keywords

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

Introduction

The Quick Response (QR) codes, developed by DENSO in 1994, are 2-D machine-readable matrix codes, more commonly known as barcodes. QR codes have been used in diverse industries since then (manufacturing, transportation, retail), but, with the growth in smartphone usage and availability, have recently moved into broader applications for the general public to utilize, such as airplane boarding passes, personal web linking, and mobile coupons[1]. Another direction of growth for QR code usage is in education at all levels. QR code usage is growing in academic settings, in part due to the simplicity and efficiency of implementing the codes. Academic uses include worksheets with solutions access, videos of practical experiments, and links to lab safety procedure, among many other possibilities[2-3]. Major advantages of using QR codes include a low-cost, easy to implement platform, highly accessible and portable medium for instruction, creation of an interactive classroom environment, and providing students with an innovative perception of classroom techniques[4].

The viability of QR code usage in the classroom has been tested at both the high school and university level for at least a decade, with mixed results. However, advances in smart-phone technology have led to recent opportunities to further integrate QR code instruction into the classroom or laboratory experience. Susono and Shimomura[5] discuss the implementation of QR codes for formative class assessment in 2006 Japan. The authors identified several challenges in

using mobile phones and QR codes in the classroom. First, students were charged for using their phone's data service. In 2006, mobile data plans were much more expensive, and Wi-Fi was not as widely supported by many phones. Additionally, not all of their students had QR compatible mobile phones. Only about 80% of the students had compatible phones at that time. Today, phones capable of scanning QR codes are standard. Another issue was the scanner/camera quality in many of the QR code-compatible phones of the time. Many of the phones would have difficulties scanning the codes due to brightness, code size, and/or focus problems. Mobile phone cameras have now significantly improved beyond this issue. Finally, the information displayed on the mobile phones would change based on the different phone companies at the time. Today the mobile web and QR code information has become very standardized across many different devices and operating systems. The researchers also asked the students, "Is it good for you to use mobile phones to improve your class or not?" Only 43% of the students said they thought the use of mobile phones improved the classroom. The students gave comments that reflected some of the problems identified by the researchers.

In late 2008, the University of Bath[6] conducted a survey of its students to determine if the student body was ready for use of QR codes in the classroom. The objective of the survey was to assess the following questions:

- Do students know what a QR code is?
- How many students have accessed a QR code on their mobile device?
- Given students' current mobile device ownership patterns, are they currently able to access QR codes?
- What support will students need to be able to access QR codes?

In total, 1790 students responded to the survey, and the results suggested that only one in ten students already knew about QR codes; and only a very small percentage, 1.58% to 2.82%, of students had accessed a QR code. Another issue was that out of the 14 most popular mobile phone models at the time, only 6 had native QR code reader software available. The researchers concluded that it was evident that QR codes were still an emerging technology and that any classroom implementation would require a large amount of support.

In another study, Rikala and Kankaanranta[7] evaluated the implementation of QR codes into multiple classroom settings in Finland. The researchers created a unique QR code based classroom activity for each of the four different age groups, spanning 9-18 years old. The first age group, ages 9-11, were tasked with QR code based trail/treasure hunt with an information retrieval component. The next age group, 10-12 years old, were given a group-based research task. Each group created a webpage discussing their research findings and created a worksheet. Each worksheet included questions and embedded QR codes linking to that group's webpage. Finally, students from around the school were tasked to complete these worksheets. The 13-14 year old age group was instructed to plan out a story by following a QR code trail in the woods. They were also tasked with planning a story using traditional methods. Finally, a small selection of 17-18 year old students were tasked with performing exercises using the proper technique shown by instructor videos accessed through QR codes on gym equipment. Response from the first two age groups, 9-12 years old, was very positive. A very large majority of these students felt that QR codes were very easy to use and that they would like to do QR activities again. The results also showed that 95% of these students thought the QR activities were an interesting new way to learn. The results from the older students was less encouraging, with students sighting the activity as flawed. However, a majority of these students agreed that QR codes were easy to use

and that QR codes should be used more in education. A further, in-depth discussion on QR codes covering their history, how they work, and their many features and applications is discussed by Sharma[8]. This paper specifically lists examples of QR codes being used in classroom teaching.

In the current paper, the usefulness of QR Code implementation in a senior-level mechanical engineering undergraduate laboratory course is discussed. QR technology provides a wealth of benefits for techno-friendly instruction. For example, the Thermal Fluids Laboratory instructor could use QR codes in distributed print media, which can contain theoretical concepts governing the current laboratory experiment, links to videos explaining lab procedure, links to web-based software that can generate plots and figures from user input data, and worked example problems. This strategy helps to tie the experiment to the theory previously taught in lecture. Therefore, the purposes of this paper is to show the integration of QR codes into the Thermal Fluids Laboratory to enhance students' learning experience and to streamline course instruction to ensure consistency across multiple sections of a course in the mechanical engineering curriculum, assisting in meeting ABET course standardization requirements.

QR Code Usage in Thermal Fluids Laboratory

Beginning in the Fall 2015 semester, QR code-assisted instruction has been utilized in Thermal Fluids Laboratory on interactive handouts given during lab. Due to software limitations, the worksheets created that allow students to generate live-updating plot data with varying input parameters is not yet accessible on a mobile phone device. Instead, QR codes linked to instructional videos for each laboratory experiment have been distributed with the assignment, along with codes linked solutions to example problems. Figures 1 and 2 show examples of QR codes distributed for interactive print media for the pump experiment and the vapor compression system experiment, respectively.

Pump Curve Experiment

Pump Information:

Grundfos CR(E)5-2 Centrifugal Pump (3/4 HP)

Test Procedure:

1) Turn on pump (110V at 60 Hz)
2) With main valve fully open: Record maximum flow rate (GPM), Pressure across pump, & Pump electrical data
3) Take the measurements of (2) for several valve positions (as it is closed)
4) With main valve fully closed, record maximum pressure across pump (at 0 GPM) and pump electrical data
5) Reopen valve and turn off pump

Figure 1. QR Code linking to video reviewing testing procedure for a lab experiment.

Example:

Given a dry bulb temperature of 85^{0}F at 50% relative humidity, calculate the wet bulb temperature from Eq.1.

Answer:_____

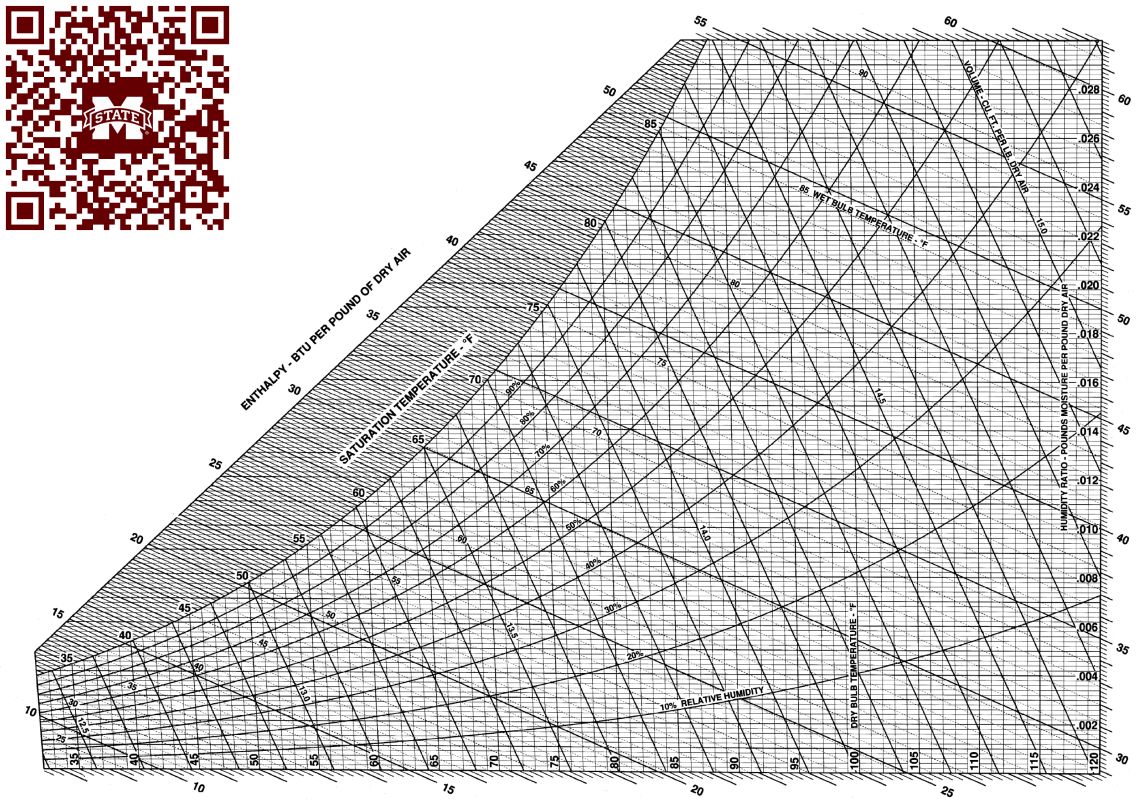

Figure 2. QR Code linking to solution to given example problem.

For the pump experiment, after the students scan the QR code (in Fig. 1) they get access to a video that clearly explains the experiment. A screenshot of the video is illustrated in Figure 3. Also, after the students scan the QR code in Figure 2, they get access to the example solution illustrated in Figure 4. These two examples show the incorporation of QR codes in two different lab experiments in the Thermal Fluids Laboratory using two different approaches: videos and homework solutions.

Figure 3. Video for the pump experiment embedded in the QR code shown in Figure 1.

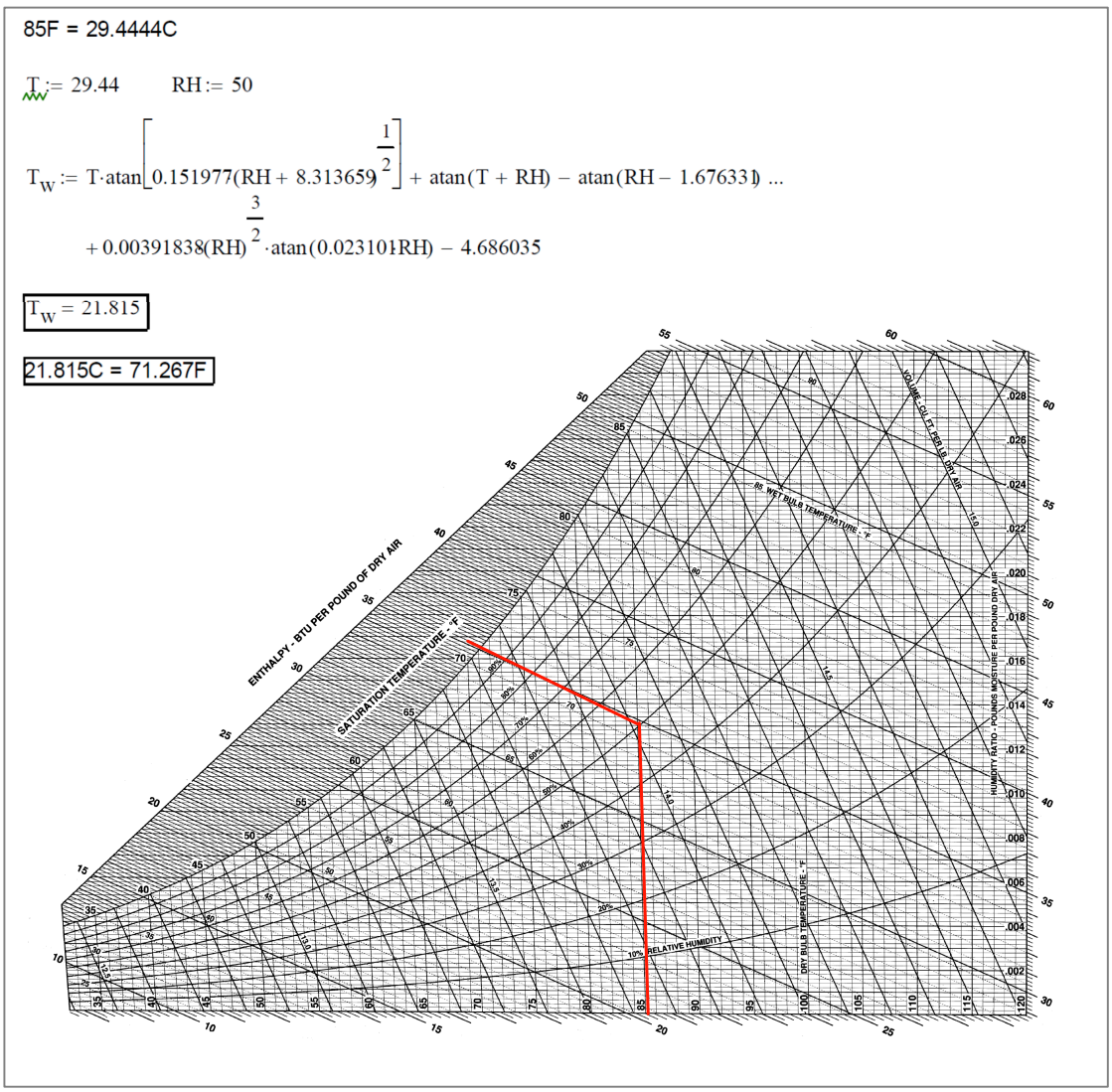

Figure 4. Solution to example problem, accessed using QR code.

Student Response to QR Code Usage

The response of students to the introduction of QR Codes in the Thermal Fluids Laboratory has been overwhelmingly positive. Though this implementation is in its first iteration, and there are several planned adaptations for QR code usage with enhanced software capabilities, the student feedback is encouraging. An optional survey was distributed to the students enrolled in the Thermal Fluids Laboratory in the Fall 2015 semester, and it was completed by 31 students. The questions asked in the survey are compiled in Table 1. Question 1 was given as a Yes/No answer, while questions 2-6 are 1-5 Likert Scale responses, with 5 representing strongly agree, 4 agree, 3 neither agree or disagree, 2 disagree, and 1 strongly disagree.

Table 1. Survey questions administered.

Question	Question Statement
Q1	Has your lab group used the course's QR code content outside of lab hours?
Q2	The QR code content has been helpful in understanding course concepts.
Q3	The QR code content was helpful when writing my lab reports.
Q4	I have a better understanding of how to operate the lab equipment because of the QR code content.
Q5	I would like to see the amount of QR code content expand for this course.
Q6	I would like to see QR code content in other engineering courses.

Student response to question 1 is given in Figure 5, and the average responses to Likert Scale questions 2-6 are compiled and displayed in Figure 6.

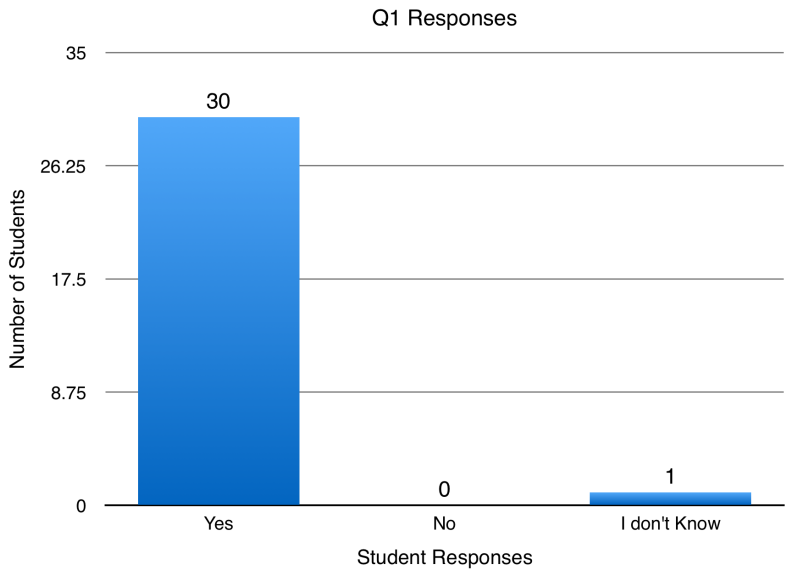

Figure 5. Response to Question 1.

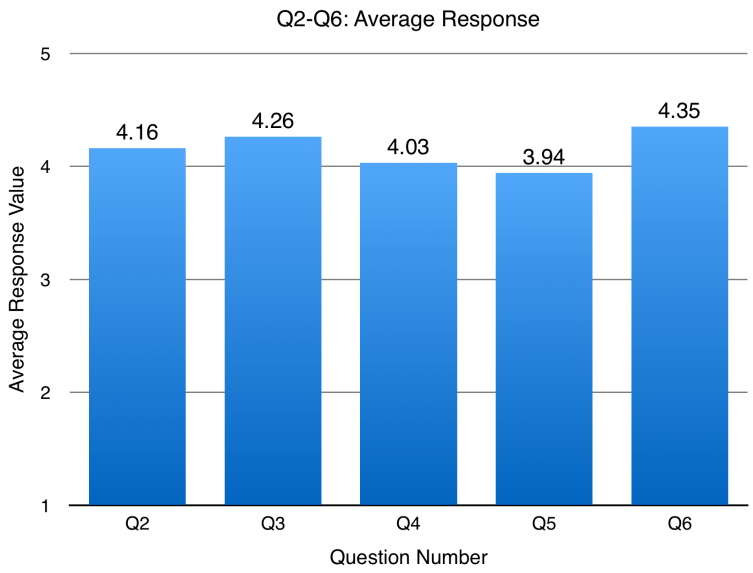

Figure 6. Average Likert response for questions 2 through 6.

As can be seen in Fig. 5, more that 96% of the students that completed the survey have used the QR codes. Also, the results presented in Figure 6 indicate that students view QR code implementation positively. Almost all of the students participating in the survey have used QR codes outside of class (Q1) to review course material and prepare for assignments. Additionally, the highest positive Likert response implied that the students would like to see QR codes implemented to a broader degree within their curriculum. The next most important aspects of QR codes to students were for assistance in writing lab reports (Q3) and for understanding course concepts (Q2). Understanding lab equipment operation (Q4) and expanding QR code usage in the Thermal Fluids Laboratory (Q5) are the responses with the lowest agreement, though still high, indicating that students are relatively satisfied with their in-class lab operational instruction and the amount of QR code content distributed, though there is still room for improvement in these areas.

Conclusions and Future Work

This paper presented the results obtained for the implementation of the interactive print media, containing quick response (QR) codes linking to video tutorials and example solutions during the Fall 2015 semester. The material that included QR codes were distributed to students in senior mechanical engineering students in a Thermal Fluids Laboratory course with each laboratory experiment studied. Student response to this implementation was very positive, and expansion of QR code content capabilities is underway. After this successful implementation of QR codes in the laboratory environment, the mechanical engineering department at Mississippi State University plans to extend this initiative to enhance other courses in the ME curriculum, including foundational lecture-based courses.

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