Work in Progress: Developing Assignments to Reinforce Process Knowledge for a Medical Equipment Troubleshooting Laboratory Course

Dr. Renata Fortuna Ramos, Rice University

Renata Ramos is an Associate Teaching Professor and the Director of Undergraduate Studies in the Department of Bioengineering at Rice University, 6100 Main St., Houston, TX 77005: rfr1@rice.edu

Miss Kathryn Kundrod, Rice University

Kathryn Kundrod is pursuing her PhD with Dr. Rebecca Richards-Kortum at Rice University. She works toward the development of low-cost HPV tests for cervical cancer screening.

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Introduction

Troubleshooting of Clinically Relevant Devices is a senior laboratory course that introduces operational principles, common failure modes, troubleshooting techniques, and preventive maintenance while focusing on six types of devices: centrifuges, refrigerators, suction pumps, syringe pumps, compound light microscopes, and oxygen concentrators. The goals of this lab are to (1) improve the students' biomedical instrumentation skills and (2) provide the students with the techniques and strategies necessary to apply a structured, logical troubleshooting process. The lab uses flipped-classroom methods to cover the operational principles of the devices. It then employs hands-on, small group (3 students per team) activities during lab time to investigate normal operation on functional devices and to troubleshoot and repair broken devices. The course is offered at two different times to keep the class size small (less than 20 students per lab section). Other than the assignment modifications described in this paper, all course materials and instructors were the same for both sections.

At the beginning of each laboratory session, students are given a working medical device and a protocol describing the steps and tools necessary to investigate normal function. Using the protocol and published device specifications, students familiarize themselves with the equipment and testing protocols. Following this process, the students are given three "broken" devices to repair. Breaks in the devices are prepared by the instructors and represent common failures modes reported for each type of device. Students are given a general problem statement regarding the failure and are then responsible for applying the troubleshooting process to logically and systematically find the failure mode or modes.

Typical assignments in this course include:

- pre-lab assignment: prior to the intervention, the prelab covered technical background on the devices; after the intervention, the prelab covered both technical information and application of the troubleshooting process.
- in-class quiz: covered technical background and troubleshooting skills for each device.
- laboratory team report: covered troubleshooting skills and required students to synthesize knowledge gained and apply it to new concepts.

The process of troubleshooting (observation, definition of problem area, identification of possible causes, determination of most probable cause, equipment testing and repair, and follow-up and preventive maintenance) is introduced during the first class and is reinforced throughout the laboratory activities as the various medical devices are introduced. Students are continuously encouraged to follow the logical, systematic troubleshooting process when working on broken devices. When students identify a failure point, the instructors inquire about how they used to troubleshooting process to reach the conclusion and how they will apply the process to test and repair the device as a next step. Instructors focus on advising students against reverting to a trial and error approach as they investigate the failures; however, some students' reliance on trial and error approaches instead of applying systematic troubleshooting methods throughout the course led to the intervention presented in this study.

Intervention

In this research study, we sought to investigate the effect of modifying pre-lab assignments from technical content-based to process-based. The goal of shifting the focus of pre-lab assignments was to help students develop an understanding of and an ability to apply the troubleshooting process, instead of developing content knowledge alone. A focus on the process was also intended to increase students' understanding of the relevance and context of the course.

Pre-lab assignments, due at the beginning of each laboratory session, were modified in one of the two lab sections to include questions about how each aspect of the troubleshooting process applies to the devices covered in that week's lab. Instead of focusing on device background and technical aspects of each device, the assignments asked the students to describe principles of operation, identify common failure points and describe the troubleshooting process that they would follow to identify and repair common failure modes for the device covered. Control (students completing standard pre-lab assignments, n=12) and experimental (students completing the modified pre-lab assignments, n=12) groups were compared in terms of (a) laboratory team report grades, (b) an end of semester quiz that focused on troubleshooting clinically-relevant equipment not covered in the lab, and (c) a qualitative survey to assess how each course assignment contributed to the process-knowledge gained in the lab. All students completed all assessments.

The quiz was graded blindly by both instructors separately, emphasizing the process and not the correctness of the answers for each one of the troubleshooting steps. A 2-tailed t-test was used to analyze report grades and quiz scores; a 2-tailed Mann-Whitney U test was used to analyze survey scores.

Results

To understand the impact of changing pre-lab assignments to focus on process knowledge, changes in a) lab report grades, b) end-of-semester quiz grades, and c) end-of-semester survey scores were analyzed (Figure 1). Lab report grades were lower (p=0.02) in the experimental group (84.1 ± 5.2%) than in the control group (88.2 ± 1.9%). The end of semester quiz grades, determined out of a total of 14 points, were not statistically different (p=0.7) between the control (6.2 ± 0.6) and experimental (6.5 ± 0.5) groups. Finally, average survey score was higher in the experimental group relative to the control group (p=0.002).

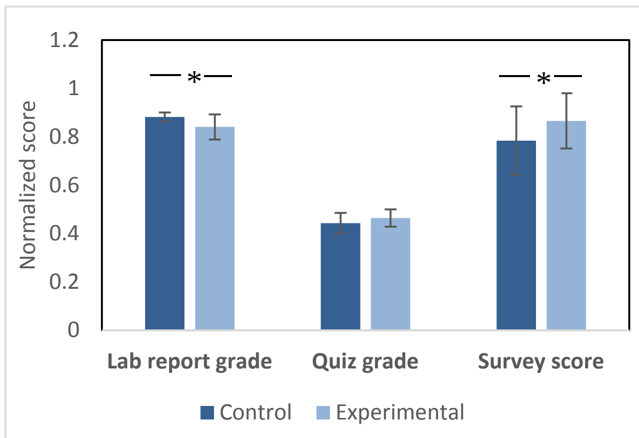

Fig. 1: Lab report, quiz, and survey scores for the control and experimental groups. Scores were normalized to the maximum possible value (100% for lab report, 14 points for quiz, and 35 points for survey). Changes in lab reports and survey scores were statistically significant (*p<0.05); quiz scores remained the same (p=0.7).

To assess how each course assignment contributes to the process-knowledge gained in the lab students were asked to complete an end-of-semester survey (Figure 2). The experimental group of students reported that *pre-lab assignments* helped prepare them to troubleshoot any equipment more so than the control group (Q2; p=0.078). Further, students in the experimental group responded with higher average survey scores, reflecting higher confidence in technical and process knowledge associated with each assignment and troubleshooting more generally, than the control group (p=0.002).

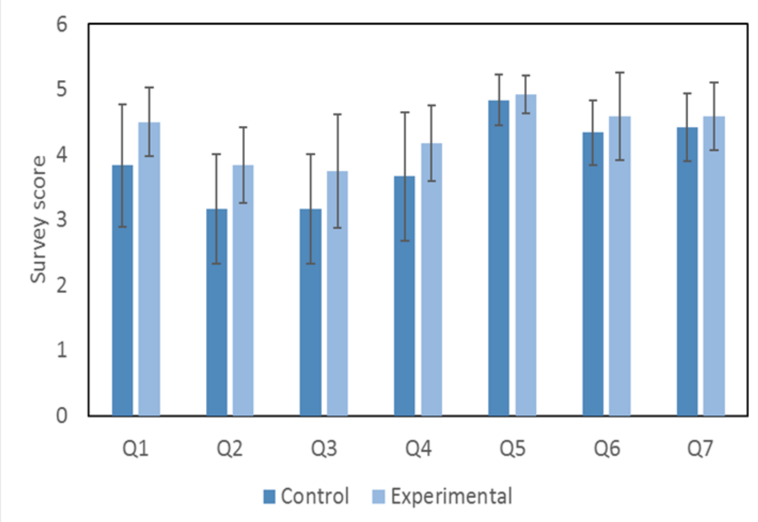

Fig. 2: Survey questions and responses. The largest average increase between groups (21.0%, p=0.078) was observed with Q2: the *pre-lab assignments* helped you develop skills on how to troubleshoot any equipment. Additional data collection is required to assess statistical significance between groups.

Respond to the following questions on a scale of 1 (low) to 5 (high):

Q1: The *pre-lab assignments* prepared you with the specific technical skills required to complete the lab

Q2: The *pre-lab assignments* helped you develop skills on how to troubleshoot any equipment

Q3: The *team lab reports* prepared you with the specific technical skills required to complete the lab

Q4: The *team lab reports* helped you develop skills on how to troubleshoot any equipment

Q5: The *in-lab activities* prepared you with the specific technical skills required to complete the lab

Q6: The *in-lab activities* helped you develop skills on how to troubleshoot any equipment

Q7: I am comfortable applying the troubleshooting process as a structured way to test and repair equipment not covered in lab

Discussion

After modifying the pre-lab assignment, students' lab report grades decreased, students' ability to describe their troubleshooting process for equipment they have not studied on an end-of-semester quiz did not change, and students' perceptions of learning both technical content and process knowledge on an end-of-semester survey increased in the experimental group relative to the control group.

From our preliminary investigation, we conclude that students demonstrated higher confidence in process-knowledge with the new pre-lab assignments. In addition, students displayed a modest, though not statistically significant improvement in learning the process over technical content based on end-of-semester quiz performance. These findings are consistent with the instructors' observations in class: students in the experimental group focused on asking and answering questions about the process; students in the control group tended to look for more obvious failure modes and seemed to rely on trial and error more frequently. Two major limitations of this study were the inability to control for inter-group differences and the small sample size. By observation of the instructors, students who sign up for the first section (the control group in this study) have always received higher grades in the reports when compared to students who sign up for the second section (the experimental group); this trend may account for the change in lab report grades observed in this study. Next year, the order of control and experimental groups will be switched to better assess the effect on lab report grades. With additional data collection, we will better understand the effects of changing the pre-lab assignments in the course with better process-knowledge outcomes. We will also assess the remaining assignments and in-class teaching methods to identify additional areas in which process-learning could be better emphasized. Developing assignments that better align with the goals of process-learning in this course will enhance student learning long term.