Cookbook Approach vs. Discovery Approach in Materials Laboratory Course at The Citadel

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Abstract

At The Citadel, Mechanical and Civil Engineering majors are required to take Materials laboratory course in the second semester of sophomore year and first semester of junior year, respectively. Two sections of the laboratory course were offered in summer of 2018. In each laboratory section, the ratio of Mechanical to Civil Engineering majors was one to one. For the purposes of this study, students performed one of two versions of tensile testing lab. One laboratory section followed a fully-guided "cookbook" approach in determining mechanical properties of metals, where the document clearly laid out each step of the experiment. While the other laboratory section followed an open-ended discovery approach, which focused on student design of experiment. Students were administered a material properties quiz to determine any outcome differences between two approaches. This paper discusses the details about the two approaches and results of the material property quiz.

Keywords

Discovery Approach Laboratory, Cookbook Approach Laboratory.

Background

Laboratory courses can be a challenging aspect of engineering education in that they typically fail to capture student interests and often exhibit a significant disparity between the laboratory setting and real-world scenarios[1,2]. As such, laboratory courses become a missed opportunity in supporting the development of problem solving and team-building skills, and the integration and synthesis of knowledge[3]. It is necessary then to construct laboratories for students that are clear in their purpose of providing students with a "hands-on" opportunity that prepares them to collect information, process that information, and report their findings on topics that they may very well encounter after their education.

Student motivation is essential when it comes to the transfer of knowledge in laboratory courses[4]. Unfortunately, laboratory courses are traditionally structured such that students are provided with a set of step-by-step instructions that lead the learner towards a pre-determined outcome, much like following a recipe from a cookbook. These "cookbook" laboratories tend to engage students at a minimal intellectual level that often only reflects how well students can follow the "recipe"[5,6,7]. Student-led scientific discovery, in which students are intellectually challenged beyond that of the basic "cookbook" laboratory, has been identified as a best practice in numerous research studies[6, 8-11]. This research has shown that student-led scientific discovery can have a positive effect on student critical thinking, engagement, performance, problem solving, self-assessment and self-confidence when compared to the standard cookbook laboratories[5-8, 12]. However, while many lecture courses at colleges and universities have implemented these techniques, there has been very little implementation of these techniques in a laboratory setting[4, 9, 13].

Research has shown that you can increase student motivation by increasing the value that students place on a task, either by having students work on real-world problems with assignments that have real-world applications or by providing them with topics that are meaningful or relevant to them[14-16]. This can be accomplished through a discovery-based approach. The discovery-based approach provides a more open-ended experience that is guided by an instructor while placing more of the observational/experimental decisions with the students to engage them in the discovery process at some level[7, 13]. The discovery approach is an inductive approach, in that it provides students with a pathway to understand the basic concepts of a topic through their own means[8]. This is a critical skill for students to develop if they are to be expected to apply previously learned knowledge to situations encountered in their careers that they have not yet been exposed to.

Discovery Approach Laboratory Section

In the discovery approach laboratory section, web-based pre-lab responses were employed to motivate students to prepare for laboratory and to inform in-class activities targeting their learning gap. Students were required to respond to one or two open-ended questions on the course website addressing the learning objectives of a specific experiment. At the beginning of the laboratory, students' pre-lab responses were summarized on the board and the common errors were discussed.

A real world application laboratory assignment was developed which required students to communicate with a client in the community. The following is a client letter addressed to students: On behalf of Built Right, Inc. I am writing to inform you that Materials Lab, Inc. has been awarded the contract for materials consulting services in support of new project in the city of North Charleston, SC. We look forward to working with your company on this important project. Built Right is in the process of evaluating the properties of materials. We need to determine the behavior and mechanical properties of mild steel, aluminum, and cold rolled steel for design of a system. We have shipped the samples of mild steel, cold rolled steel, and aluminum to you. We request that you perform the appropriate tests to determine important mechanical properties, stress-strain plots, and to design rod BD for the system (Figure 1). Please consider the following criteria in your designs: the deflection at point C on the rigid bar should not exceed 0.10 inches.

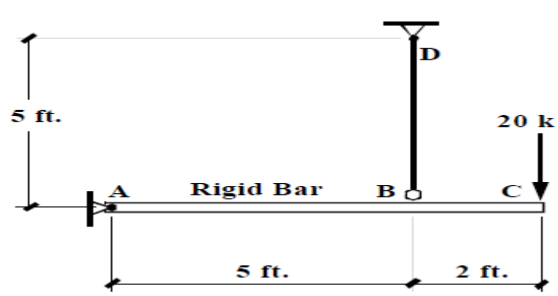

Figure 1. Schematic of the assigned design problem

Students were tasked to design an experiment and document the design in a written three-page proposal. The students were instructed that the proposal should not resemble a laboratory manual with a set of instructions. Instead, it was required to include the following items: the purpose for writing; the problem being solved; the specific laboratory tests that will be conducted; the important equipment that will be used; how the tests will be set up and conducted; how many tests will be conducted; and a detailed plan for how they will analyze the data to obtain an appropriate mechanical properties (modulus of elasticity, the yield strength of the materials, etc.). Once the proposals were submitted and accepted, students in teams of five conducted the experiment using the available materials in the laboratory. The experiments were performed in teams, due to equipment and time constraints. Lastly, students were asked to write formal report to describe their work. They also provided recommendations on type of material needs to be used to design bard BD based on the material properties and cost of specimen.

Cookbook Approach Laboratory section:

In the cookbook approach laboratory section, instructor explained the laboratory procedures and demonstrated the experiment to the class. Students were instructed to conduct tensile testing experiments to obtain stress-strain diagrams and mechanical properties for aluminum, cold-rolled steel, and mild steel using the following step-by-step procedure:

1. Measure and record the diameter of each specimen.
2. Install the specimen in the universal testing machine, taking care to align the specimen with the loading axis of the machine (this is performed by the instructor).
3. Determine the appropriate loading increments for the material to be tested. The load increments should allow for more data to be collected near the yield point. After the yield point has been reached, record data at load intervals of 1000 pounds. Record the data in Table 1.
4. After failure, carefully remove the specimen from the testing machine. Observe and measure the failure surface.
5. Plot the complete stress-strain curve.
6. Calculate and tabulate the following: yield point; ultimate stress; failure stress; modulus of elasticity; modulus of resilience; modulus of toughness.

Table 1. Tensile Testing Data Sheet for Cookbook Laboratory Section

Load (lb)	Axial strain (Aluminum)	Axial strain (Cold Rolled Steel)	Axial strain (Mild Steel)

After the laboratory reports were submitted, students were administered a material properties quiz (see Table 2 and Figure 2) to determine any outcome differences between two approaches. We have found that most students have difficulties with concepts such as ductility/brittleness, stiffness, and yield stress. Therefore, the quiz was designed specifically to capture the student understanding of the stated concepts. One of the authors graded the quiz for both sections to ensure uniform application of grading rubric.

Table 2. The material properties quiz

Q1	Which material is the most ductile in Figure below?
Q2	Which material is the most brittle in Figure below?
Q3	Which material has the largest modulus of elasticity in Figure below?
Q4	Estimate the yield stress for 1060 CR Steel in Figure below using an acceptable approach.

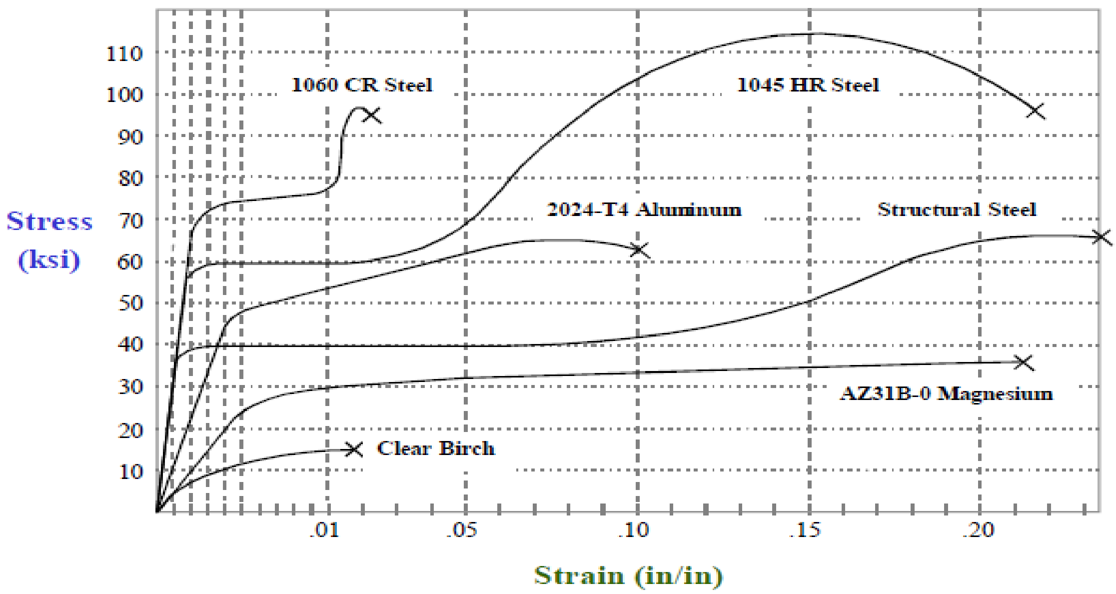

Figure 2. Stress-strain plots of several materials utilized for the direct assessment

Figure 3 illustrates the average student scores and analyzes students' performance on each question on the material property quiz. In the cookbook approach section, the standard deviation for questions 1 through 4 were 44.7, 40, 44, and 35, respectively. In the discovery approach section, the standard deviation of questions 1 through 4 were 36, 37, 28, and 18, respectively. Students in the discovery approach section (n =14) outperformed students in the cookbook approach section (n =16) on every question and overall. The results clearly indicate that student performance was increased at least 12% on all four questions of the material property quiz in the section in which students had used the discovery approach laboratory.

It was hypothesized that the students who had to design their own experiment would better understand the ductility/brittleness, stiffness, and yield stress concepts than the student who completed the cookbook approach. A two-sample t-test statistical analysis at five percent level of significance (α =0.05) was conducted to see if there is a significant difference between the results of the discovery section (Mean = 88.5) and cookbook section (Mean = 79.5). The results showed that students who completed the discovery version of the lab performed better than their peers who completed the cookbook approach (p-value = 0.021).

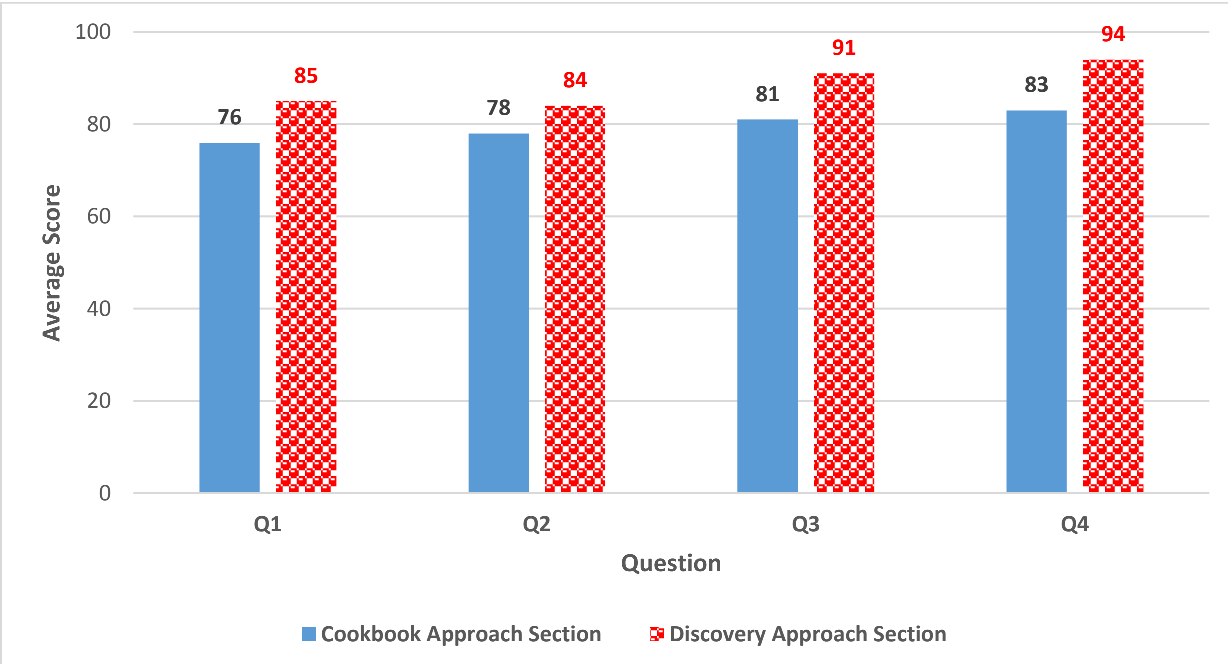

Figure 3. Results of material property quiz.

Conclusions

A study was conducted to assess the influence of discovery approach laboratory instruction on student learning outcomes. The results showed that students who completed the discovery version of the lab performed better on a quiz related to the lab concepts than did their peers who completed the cookbook approach. This results suggests that having students design their own experiment may make them more likely to have better understanding of the concepts. However, it is difficult to move beyond observations into recommendations due to the small sample size. Further data collection and analysis is warranted over the next few offerings before conclusions can be made, especially since the improvement of about 12% is modest.

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