From Tensile Testing to Generating Crossword Puzzles

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Abstract

To enhance the Materials Laboratory course offered in summer 2015 and to improve the student learning environment, a wide variety of teaching and learning tools were employed. These included incorporating learning objectives directly into the teaching of the course materials; pre-lab reading responses on the course website; relating the presented material to previous and future materials in the course and to the student's personal experience; summarizing and correcting the misconceptions on pre-lab responses at the beginning of each lab; developing "real world" laboratory assignments; games; Minute paper; think-pair-share; recitation and technical writing workshops and a number of other teaching and learning techniques. Student perceptions of usefulness of the various teaching and learning tools were surveyed at the end of the course. Survey results provide insight on the usefulness of the various learning tools.

Keywords

Active Learning, Materials Laboratory, Pedagogy.

Background Information

Laboratory courses are the most challenging aspect of engineering education[1]. They are often characterized by inadequate resources, lack of students' interest[2], disparity between them and real life scenarios[2]. Students typically perform a set of instructions without understanding the reasoning behind them[2], and thus, students come to the laboratory unprepared. In addition, there is not enough attention given to the technical writing.

To maximize student learning, it is essential to develop ways to promote student motivation. Motivated students strive to make the most of their education by acquiring new information and using it to further their knowledge[3, 6]. To increase the value that students place on a task, it is helpful to relate it to their interests [3- 5]. If students are able to work on a topic that has meaning or relevance to them, they are more likely to see the value and become more motivated[3]. One way to increase student's motivation is to provide them with assignments that focus on real-world applications. By focusing on real-world problems, students get to see the actual applications of the theories learned in class[3-5]. Ambrose et al. recommend using real-life examples of problems, case studies, and discussions on current events to help students see their classroom material come to life[6]. Another way to increase motivation is by incorporating technical writing assignments to introduce and reinforce skills, techniques, and work habits for writing effectively and efficiently in an engineering context. Technical writing, in fact, may consume the majority of labor hours of a practicing engineer. Strong technical writing skills and the ability to interact collaboratively to produce high-quality deliverables are critical elements that govern the success and career advancement of individual engineers and, ultimately, the success of their respective companies.

Materials Laboratory Summer Course at The Citadel

Courses offered in the summer usually attract a diverse population of students. Students are faced with a very different environment than would be found during the fall and spring sessions. At The Citadel during the fall and spring, classes are taken primarily by members of the Corps of Cadets. A relatively small percentage of the classes are occupied by active duty or veteran students who are taking day classes with the Corps of Cadets. Evening classes at The Citadel are populated with students who live in the community, many of whom are working part-time or full-time. Some veteran or active duty students may be included in the evening classes. Those classified as day students may also attend evening classes.

The Materials Laboratory course is required of students in both the Civil and Mechanical Engineering programs. Students in the evening program may only take the Materials Laboratory during the summer term. Students taking the Materials Laboratory in the day program usually take the course during the fall or spring semester, but may also register for the course in the summer.

Summer sections of the Materials Laboratory primarily have Mechanical and Civil Engineering evening students, but may also have Cadets, day students, active duty students, and veteran students. Evening students may be employed part-time or full-time and students who normally attend school in the day program may have summer jobs. Finally, students may have been taking courses at The Citadel for two or more years and other students may be students in a 2+2 program who are taking the Materials Laboratory as their initial course at The Citadel.

For such a diverse group of students, who have different working and academic experiences, it is imperative to design the course to address the needs of the different learning preferences in the classroom. Student motivation is driven by the manner in which the course is designed and the effort put forth by the course instructor in trying to meet the learning needs of all students in the classroom.

Active Learning Techniques Used

To enhance the course and to improve the student learning environment, a wide variety of teaching techniques and activities were employed. These included incorporating learning objectives[7] directly into the teaching of course materials; pre-class responses on the course website; summarizing and correcting the misconceptions on pre-lab responses at the beginning of each lab; relating the presented material to previous and future materials in the course and to the student's personal experience; employing question and answer methodology; developing "real world" application laboratory assignments; crossword puzzles; Pictionary; Jeopardy-style questions; Minute paper; think-pair-share; recitation and technical writing workshops; student-to- student interactions and faculty – students interactions; and a number of other teaching and learning techniques.

Web-based pre-class reading responses[8] were employed to motivate students to prepare for laboratory regularly. Students were required to respond to two or three open-ended questions on the course website addressing the learning objectives of a specific experiment. Immediately before class, student responses were examined and the in-class activities were tailored to meet their actual needs. The following is a typical pre-class response on the course website:

1. Name an application or situation where torsional deflection is undesirable. Name an application or situation where torsional deflection is desirable.
2. What would happen to the relative stiffness of the rod if the diameter were increased?
3. Briefly describe how you determine the value of shear modulus of material.

At the beginning of each lab, student's pre-lab responses were summarized on the board and the common errors were discussed**.** Following the discussion, Think-Pair-Share technique [9] was employed to help students organize prior knowledge, brainstorm questions and engage with the concepts. This strategy provided students time and structure for thinking on a given topic, enabled them to formulate individual ideas and share the ideas with a peer.

Real world application laboratory assignments were developed which required students to communicate with a client in the community. The following is typical memorandum from a client to the students in Materials Laboratory course: "On behalf of Built Right, Inc. I am writing to inform you that Materials, Inc. has been awarded the contract for materials consulting services in support of a new project in 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 (see Appendix). Please consider the following criteria in your designs: the deflection at point *C* on the rigid bar should not exceed 0.15 inches."

Recitation sessions were conducted to guide students in reviewing important mechanics of materials concepts such as stress-strain; torsion; shear and bending moment; bending stress; and deflection. Technical writing workshops were conducted to introduce students to the engineering writing process; writing memorandum and formal laboratory reports; and introducing students to the Do's and Don'ts for creating high quality figures and tables. One-Minute paper[10] was used to monitor student learning, which required students to answer a "big picture question" from the material that was presented in the current or previous laboratory in 60 seconds.

Students were also required to generate a crossword puzzle by incorporating one aspect of each of following terms or concepts**:** modulus of elasticity; regions of stress-strain curve; proportional limit stress; yield stress; ultimate stress; engineering failure stress; true failure stress; modulus of resilience; modulus of toughness; percent elongation; 0.2% offset method; ductile materials; brittle materials; modulus of rigidity; polar moment of inertia; Poisson's ratio; bending stress at neutral axis; moment of inertia; neutral axis; bending stress at outer fibers of beam; shear forces-simply supported beam; bending moment of a simply supported beam; deflection of a simply supported beam. Once constructed, the puzzles had to be solved by other students in the laboratory. Kangas states that this kind of class activity encourages students to take a greater degree of responsibility for their learning, lets them become more active participants of the learning process and makes them feel more in control of their own learning and thinking[11]. A sample student generated crossword puzzle is included in the Appendix.

To review for the final exam, Jeopardy-style questions (Figure 1) and a game of Pictionary were employed requiring students to display content mastery that goes beyond simple memorization of facts. Category topics for the Jeopardy included: tensile testing, torsion testing, bending stress of beam, shear and bending moment, and deflection of a beam. Each group selected a topic and chose a dollar value for the question. The complexity of each question increased as the dollar value increased. When playing the game of Pictionary, the class was split into two groups and students were given five minutes to write down words that capture any concept that had been covered in the course. Next, the ten best words were selected and each was written on its own index card. Students were asked to draw on the board to covey the meaning of the words. Each group had seven minutes to see how many of the other groups' words or phrases they could guess. The group with the lowest combined time was the winner.

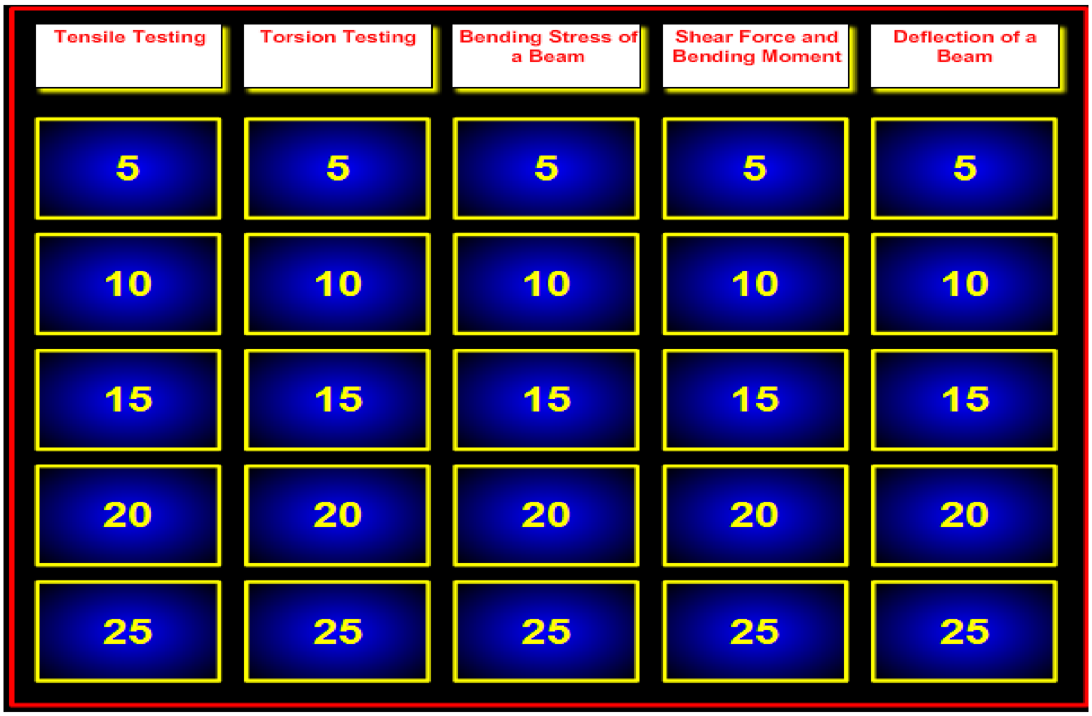

Figure 1. Jeopardy game used to review for the final exam

Survey on Student Perception of Learning Tools

Student perceptions of usefulness of the various teaching and learning tools were surveyed at the end of the course. Two sections of the Materials Laboratory were taught by the same instructor (Ghanat) and there was no substantial difference in the results from the two sections. Data from the two sections were treated as a single sample in the following figures and table. Survey results are shown in Figures 2-12 and Table 1. Each numbered survey question is shown as the title of the corresponding figure number. Twenty-six of the twenty-seven students in the two sections completed the survey. The survey used a five-level Likert-type scale for response and is included in the Appendix. Students were asked to rate each teaching and learning tool as least useful (1) to most useful (5). Overall, student's responses reflected a positive perception of the teaching and learning tools.

Student's perception of how useful the real-world design laboratory assignments were in helping them to learn the course material is shown in Figure 2. Eighty-eight percent of the students rated the real world design laboratory experiment as either 5 out of 5 or 4 out of 5, with 5 representing the most useful. The average Likert value was 4.6. As shown in Figure 3, 88% of the students rated the interaction with the professor highly in helping them to learn the course material. However, only 48% of the students rated the interaction with their peer highly. One hundred percent of the students rated the interaction with professor as either 5 out of 5 or 4 out of 5, with 5 representing the most useful. An average rating of 4.88 out of 5 indicated that students perceived that the interaction with the instructor contributed significantly to the learning of the course material.

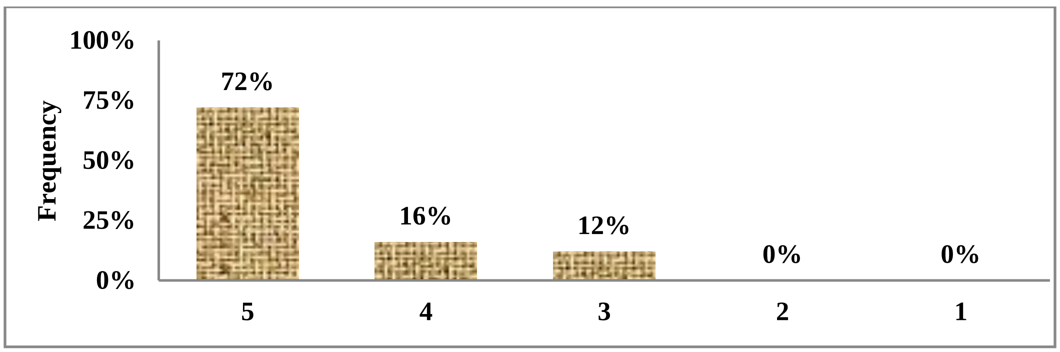

Figure 2. How useful were the real-world design laboratory assignments in helping you to learn the course material (5 is Most)?

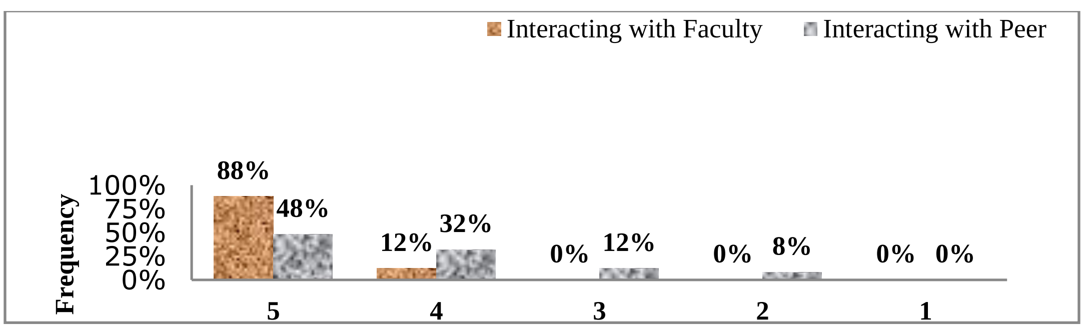

Figure 3. How useful were the interactions with faculty and peer in helping you to learn the course material (5 is most)?

Figure 4 provides the results of the student perception of usefulness of incorporating the learning objectives into the teaching and learning of course material. The average Likert value and standard deviation were 4.92 and 0.27, respectively. In Figure 5, student ratings are shown for pre-laboratory responses on the course website submitted before each lab. Seventy percent of students perceived the pre-lab responses as useful in learning the course materials. Eighty percent of the responses were 5 out of 5 or 4 out of 5 and the average Likert value was 4.2. It is important to note that the responses to this question resulted in the largest standard deviation which was 0.94. Figure 6 illustrates student's perception of usefulness of summarizing and correcting the misconceptions on the pre-lab responses. Figure 7 illustrates that 96% of students perceived the recitation classes and technical writing workshops as very useful in helping them to learn the course materials. The average Likert value and standard deviation were 4.68 and 0.55, respectively.

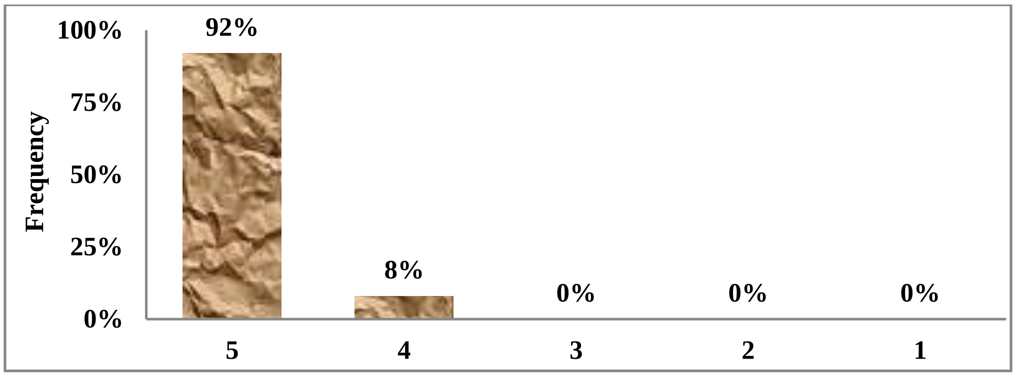

Figure 4. How useful were the learning objectives in helping you learning the course material (5 is most)?

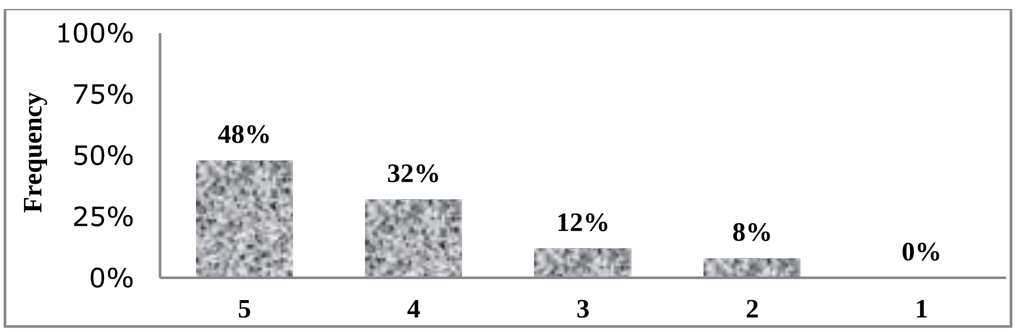

Figure 5. How useful was the pre-lab responses on the course website in helping you to learn the course material (5 is most)?

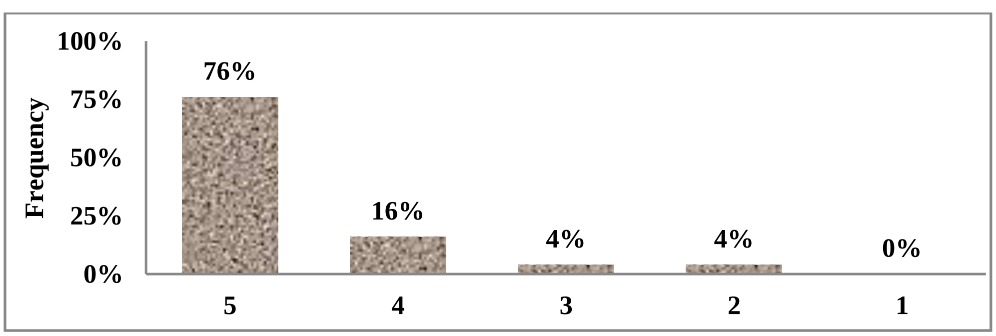

Figure 6. How useful were summarizing and correcting the misconceptions on pre-lab responses at the beginning of lab in helping you to learn the course material (5 is most)?

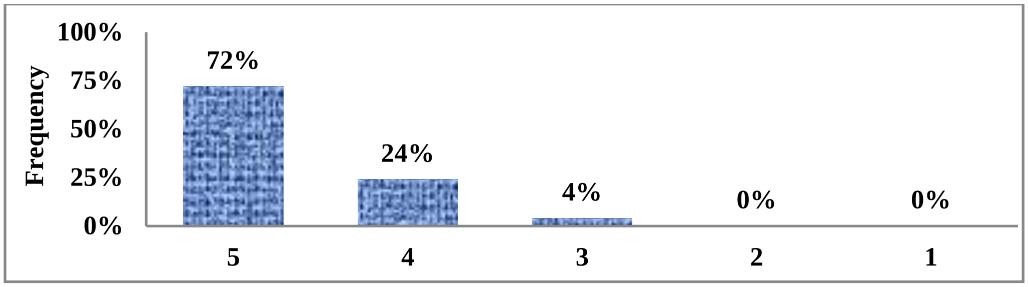

Figure 7. How useful were the recitation and technical writing workshops in helping you to learn the course material (5 is most)?

As shown in Figure 8, eighty-eight percent of the students perceived that relating the presented materials to previous and future materials in the course as useful tool in helping them to learn the material. The average Likert value was 4.84. Figure 9 shows that eighty-eight percent of students felt that the minute papers were very useful in helping them to learn the material. Figure 10 shows that ninety-two percent of students perceived the Think-Pair-Share activity as a very effective learning tool.

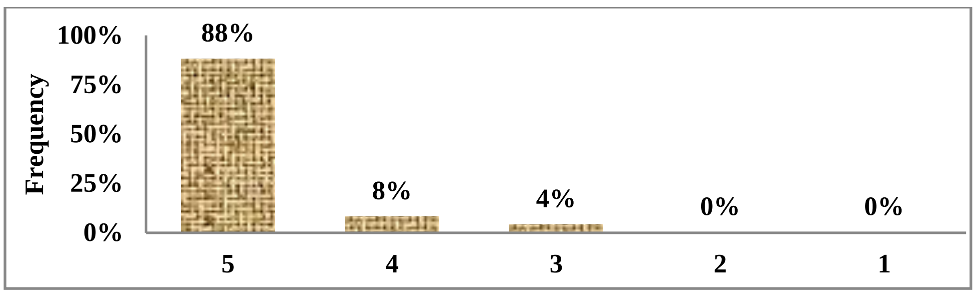

Figure 8. How useful was relating the presented materials to previous and future materials in the course in helping you to learn the material (5 is most)?

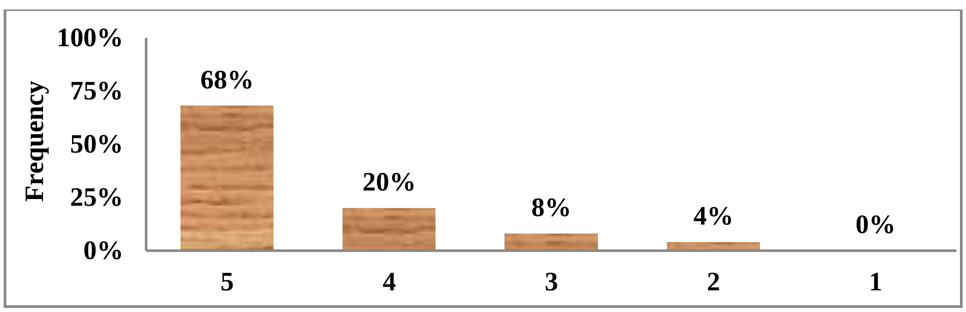

Figure 9. How useful was Minute paper in helping you to learn the course material (5 is most)?

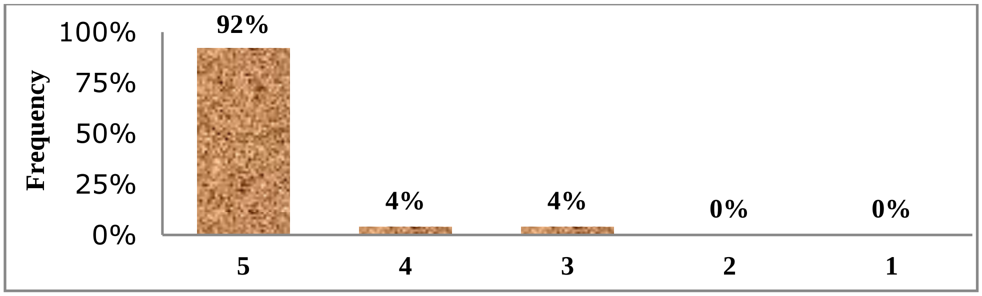

Figure 10. How useful was think-pair-share activity in helping them to learn the course material (5 is most)?

The survey results shown in Figure 11 indicate that all students provided a usefulness rating of 5 out of 5 that receiving rapid feedback was extremely important in learning the course material. When asked about the usefulness of employing games, students responded as shown in Figure 12. Ninety-six percent of the responses were 5 out of 5 or 4 out of 5 and the average rating was 4.7 out of 5 as shown in Table 1.

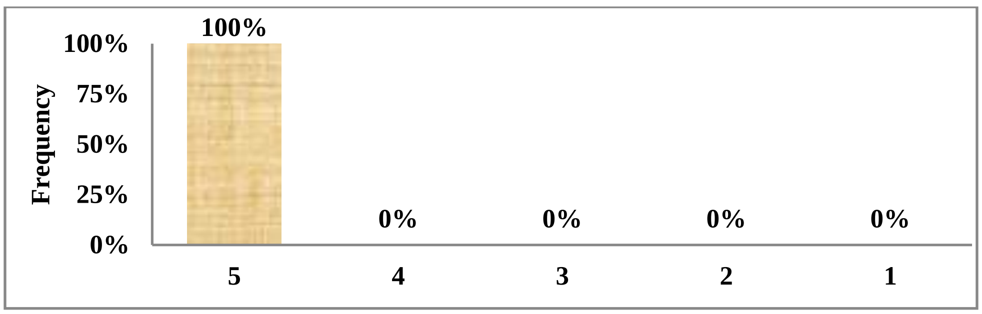

Figure 11. How useful was receiving rapid feedback in helping you to learn the course material (5 is most)?

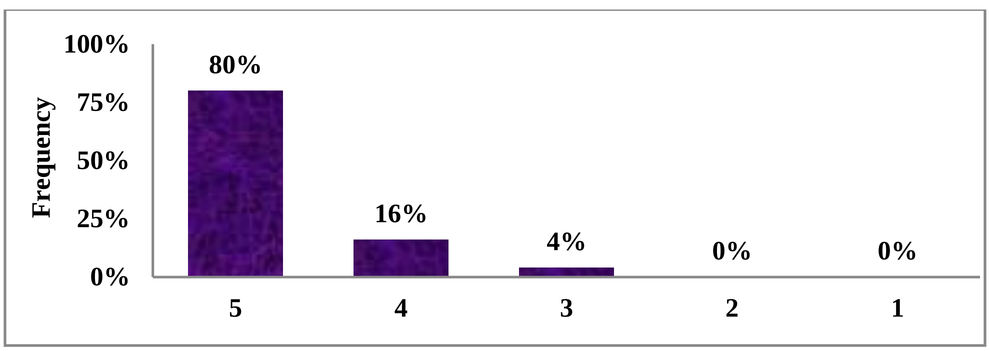

Figure 12. How useful were the games in helping you to learn the course material (5 is most)?

Table 1. The survey results summary statistics

Questions	Mean	Standard Deviation
1	4.6	0.69
	4.88	0.32
2	4.2	0.94
3	4.92	0.27
4	4.2	0.94
5	4.64	0.74
6	4.68	0.55
7	4.84	0.46
8	4.6	0.81
9	4.88	0.43
10	5	0
11	4.7	0.52

Concluding Comments

A variety of teaching and learning tools were employed in a summer offering of Materials Laboratory course at The Citadel. These techniques engaged and motivated students to learn the fundamental mechanics of materials concepts. The effectiveness of these techniques was assessed indirectly by examining student responses on a self-perception survey. More than eighty-five percent of students rated incorporating learning objectives, interaction with faculty, relating the presented material to previous and future materials in the course, think-pair-share and rapid feedback as most useful. This study represents an initial look at the value to students of active teaching and learning tools in a laboratory course. Future work would be needed to verify the impact of the teaching and learning tools on student performance. As noted previously, the student perception was that adding active teaching and learning tools to the laboratory instruction could make it significantly more valuable. Active learning tools used in this study can clearly enhance and support traditional methods of instruction typically used in laboratory courses. With this in mind, engineering educators who teach laboratory courses may want to consider adding several of the activities employed in this study to the set of teaching techniques and activities used in their laboratory courses.

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John Murden

John A. Murden is an Associate Professor of Civil and Environmental Engineering at The Citadel in Charleston, South Carolina. He obtained his B.S., M.S. and Ph.D. degrees in Civil Engineering from Clemson University in 1977, 1984 and 1987 respectively. His industrial experience encompasses aerospace structures, shipboard structures and nuclear engineering. Dr. Murden's research interest are in Engineering Education, experimental methods in mechanics and system modeling. He has served on The Citadel faculty since 1989.

APPENDIX

CIVL 307 Class Survey

How useful were the following learning tools in helping you to learn the course material?	**Least**				**Most**
1. The real-world design laboratory assignments **(5 is the most)**	**1**	**2**	**3**	**4**	**5**
2. A)Interactions with faculty **(5 is the most)**	**1**	**2**	**3**	**4**	**5**
B) Interactions with peer **(5 is the most)**	**1**	**2**	**3**	**4**	**5**
3. Use of learning objectives (**5 is the most**)	**1**	**2**	**3**	**4**	**5**
4. Pre-lab responses on the course website (**5 is the most**)	**1**	**2**	**3**	**4**	**5**
5. Summarizing and correcting the misconceptions on pre-lab responses at the beginning of lab (**5 is the most)**	**1**	**2**	**3**	**4**	**5**
6. Recitation and technical writing workshops **(5 is the most)**	**1**	**2**	**3**	**4**	**5**
7. Relating the presented materials to previous and future materials in the course **(5 is the most)**	**1**	**2**	**3**	**4**	**5**
8. Employing Minute paper **(5 is the most)**	**1**	**2**	**3**	**4**	**5**
9. Employing Think-Pair-Share activity **(5 is the most)**	**1**	**2**	**3**	**4**	**5**
10. Receiving rapid feedback **(5 is the most)**	**1**	**2**	**3**	**4**	**5**
11. Employing games such as Jeopardy, Pictionary or Crossword puzzle. **(5 is the most)**	**1**	**2**	**3**	**4**	**5**

BUILT RIGHT, INC
123 Stress-Strain Drive, Suite 101
North Charleston, SC
843-777-1234

Dr. Ghanat

Materials, Inc.

The Citadel

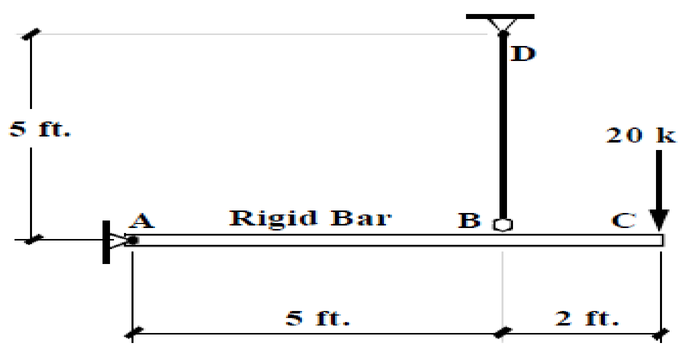
Charleston, SC 29409

RE: Materials consulting (New Project)

Dear Dr. Ghanat:

On behalf of Built right, Inc I am writing to inform you that Materials, Inc has been awarded the contract for materials consulting services in support of new project in 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 below. Please consider following criteria in your designs: the deflection at point *C* on the rigid bar should not exceed 0.15 inches.

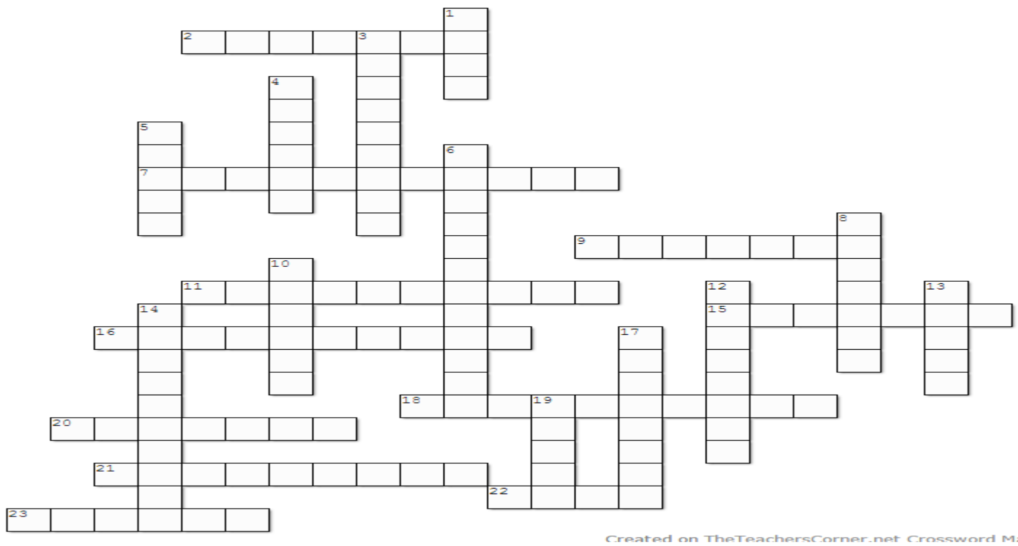


Please send us a formal report containing your findings and recommendations by October 6, 2015. If you have any questions regarding this letter, feel free to contact me at (843) 777-1234.

Sincerely,

Andy Yield

Project Manager



Across

- **2.** Materials that break before significant deformation
- **7.** ___ failure stress = Applied force/original area
- **9.** Materials that can be deformed temporarily
- **11.** (Deformed length - initial length) x 100% = Percent ___
- **15.** Moment of ___ determines the torque needed for angular acceleration about a rotation axis
- **16.** Degree to which a beam is displaced under a load
- **18.** Modulus of ___ is the straight-line slope of the deforming portion of the stress-strain curve
- **20.** Ratio of transverse and axial strains
- **21.** ___ Testing Machine used in the first portion of laboratory experiments
- **22.** ___ failure stress = Applied force/deformed or 'necked' area
- **23.** Applied force/Area = ___

Down

- **1.** Amount of bending stress in neutral axis
- **3.** Modulus of ___ = On a stress-strain curve, the total area up to the failure point
- **4.** Deformed length/Original length = ___
- **5.** The point of highest stress and strain before permanent deformation = ___ limit
- **6.** ___ limit; top of the straight-line portion of the stress-strain curve
- **8.** ___ axis is at the centroid
- **10.** Bending ___ is caused when an applied force causes a beam to bend
- **12.** Modulus of ___ is the ratio of shear stress to shear strain
- **13.** The 2% offset method for ___ strength
- **14.** Modulus of ___ = On a stress-strain curve, the area under the elastic portion before the yield point
- **17.** The highest point of stress that an object could have applied
- **19.** ___ forces push part of an object in opposite direction from the rest