MiniLab Round Robin: An Alternative to Demo Labs

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Abstract

Demonstration labs developed to supplement lecture-based delivery of an undergraduate materials science course were passive, visual and aural learning experiences. Originally intended to engage students, the demo lab proved to be little more than a lecture with props. Recognizing the importance of active cooperative learning, the MiniLab Round Robin was developed to deliver hands-on team-based learning activities, during class time and *with no* traditional lecture support. The paper describes the development and delivery of the cooperative learning activity, results and feedback and instructors' reflections and recommendations for future improvement.

Introduction

Engineering Materials Science, ENGR 340, is a core 3 credit hour course offered to junior level students in all engineering disciplines at the College of Engineering and Computer Science at the University of Tennessee at Chattanooga. Historically, ENGR 340 was delivered in a traditional teaching centered lecture format comprised of three lectures per week, homework assignments and mid-term quizzes and a final exam. Teaching the course for the first time in 1998, Goulet sought to enhance the learning experience by incorporating active and cooperative activities[1-3] including mandatory and random pre-lecture student recitations, demonstration labs to supplement lecture and cooperative or self-directed learning activities that replaced lecture entirely. Improved outcomes attributed to the pre-lecture recitation and to learning activities in lieu of lecture were observed in class attendance, preparedness, participation and office visits. The demonstration labs seemed to have little impact, however.

The demonstration labs dovetailed with lecture content, exposed students to test equipment, materials, and procedures subsequently challenged learners with assignments related to data analysis and results presentation. By observation, however, the demonstration labs failed to effectively engage the students. This shortcoming was attributed to the passive, hands-off, visual and aural nature of any lecture with props where the specimens, equipment, and data acquisition systems were prepared, setup and configured in advance by the instructor or teaching assistant.

Seeking to enhance the learning experience by incorporating active and cooperative activities while mindful of available resources and constraints, the authors set out to develop and deliver hands-on laboratory experiences that actively and cooperatively engaged all students toward the achievement of the course learning objectives *with no* traditional lecture support. The learning activity, named the MiniLab Round Robin, entailed setting up a number of different laboratory activities planned and executed in one class session by small teams of 4 to 5 students. The teams would then rotate through the remaining lab stations in consecutive 75-minute class meetings. At the conclusion of the round robin, reports would be collected and an exam administered.

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Developing the MiniLab Round Robin

While sets or rounds of MiniLabs could have been designed to support any of the numerous topics or themes relevant to an undergraduate materials science course, the topics chosen for the first project revolved around experimental testing and measurement to determine the mechanical properties of engineering materials and, more importantly, to determine the effect of some test variable on those properties. This decision was based on the availability of equipment, the planned adaptation to an undergraduate strength of material course in the fall of 2001 and the authors' research interests. The design project was kicked off in September 2000 and completed in October 2000. The development process is presented below in the following steps: establishing goals and objectives, defining specifications and constraints, gathering information and idea generation, evaluation and preliminary design, detailing and construction.

Goals and Objectives

The primary goal of the MiniLab round robin design project was to develop and deliver hands-on laboratory experiences that actively and cooperatively engaged all students toward the achievement of the following course learning objectives *with no* traditional lecture support. *The learner will know, understand and apply a) the principles of materials testing to determine the mechanical properties of materials; b) useful PC based tools and technologies for testing and measurement, data acquisition and analysis and the presentation of results; c) skills in self-directed learning, cooperative learning, teamwork and communication.*

Specifications and Constraints

The success of the MiniLab round robin depended on the degree that the Goals and Objectives would be satisfied within the context of existing realities. The following specifications flowed from the goals and instructional objectives stated above while the constraints arose from ordinary institutional and funding realities.

Specifications:

1. The level and content of the MiniLab round robin learning activities should be consistent with the fundamental principles and concepts introduced in ENGR 340.
2. The labs should involve testing and measurement techniques to determine mechanical properties of engineering materials.
3. Techniques would utilize PC based tools and technologies for data acquisition, analysis and presentation.
4. All students should participate as part of a team in execution of the lab tasks including pre-lab preparation, planning, specimen preparation, testing, data acquisition and analysis, and the presentation of results.
5. Student under-participation and over-participation should be minimized.

Constraints:

1. The labs should utilize available equipment while the department will provide consumables.
2. The labs should take place within the regularly scheduled lecture time in an available laboratory.
3. Impact on the students' out of class workload should be minimized.

Information Gathering and Idea Generation

To encourage active and cooperative student engagement, the authors chose to limit team size to 4, and given the class enrollment, set out to identify five lab station topics to serve five teams. Before proposing possible lab topics, an inventory of *available* lab equipment was undertaken. Equipment generally available in the undergraduate strength of materials lab included:

60-ton Tinius Olsen tensile tester with grips, extensometers, DAQ and PC
Leco hardness tester

Charpy impact tester
Manual rolling mill
Oven and Freezer
Digital calipers

Equipment in the UTC Biomechanics and Materials Testing Lab that could be *borrowed* for scheduled time intervals included

Instron bi-axial servo-hydraulic test frame with fixtures, extensometers, PC controller and DAQ
Buehler metallographic saw, mounting press, grinder and polisher
Nikon inverted metallograph
Digital imaging system with CCD camera, frame grabber and PC based data acquisition system
Correlation Systems image correlation utility for full field 2-D displacement measurement

With an inventory of available equipment in hand, a list of possible lab topics was generated. Although this step of the development process included a cursory search of engineering education journals, publications and textbooks and queries of colleagues, the list is perhaps more reflective of the authors' interests, experience and expertise. The list of possible lab topics considered included:

1. Effect of strain rate on the modulus of elasticity of polymers
2. Effect of strain rate on the tensile strength of polymers
3. Effect of strain rate on the % elongation at failure of polymers
4. Effect of cold-work on the yield strength of body- & face-centered cubic metals (BCC & FCC)
5. Effect of cold-work on the % elongation at failure of BCC and FCC metals
6. Effect of cold-work on the hardness of BCC and FCC metals
7. Transition temperature phenomenon and the Charpy specimen
8. Tensile strength of ceramics and the Weibull statistic
9. Rupture strength of anisotropic material (wood)
10. Effect of water-cement ratio on compressive strength of concrete
11. Effect of curing time on the compressive strength of concrete
12. Determining Poisson's ratio of an elastomer using digital image correlation
13. Cold work, recovery and recrystallization of FCC metals
14. Fatigue crack propagation and the endurance limit in steel and aluminum
15. Effect of temperature on the creep modulus of polymers using digital image correlation

Evaluation and Preliminary Design

The list of possible topics was narrowed down through a process of elimination by applying the criteria contained in the specifications and constraints. The 75-minute time constraint was applied to eliminate topics 10, 11, 13, 14 and 15. The fatigue crack propagation test in topic 14 could easily exceed 4 hours while the creep moduli tests in lab topic 15 have typical durations of 10, 100, and 1000 hours. Similarly, the time and sequencing related to specimen preparations in lab topics 10, 11 and 13 would prohibit completion in 75 minutes. Regarding specimen preparation, it was judged that the hands-on learning experience would be substantially compromised if the instructors prepared specimens in advance.

Level and content specifications eliminated topics 1, 2, 3, and 9. Strain rate effect is an advanced topic not covered in this introductory materials science course while topic 9 was eliminated due to its limited content and interest.

The remaining 6 topics generally satisfy the criteria contained in the stated specifications and constraints. After combining 4, 5 and 6 the following *preliminary* MiniLab Station Titles were developed:

Effect of Cold Work on the Yield Strength, % elongation and Hardness of BCC and FCC metals
Transition Temperature phenomenon and the Charpy Specimen
Tensile Strength of Ceramics and the Weibull Statistic

The number of topics fell one short of the five that was originally targeted. The authors decided to proceed with these four topics and anticipated that the increase in maximum team size, 4 to 5, would not adversely affect outcomes.

Detailing and Construction

Generally, detailing precedes construction, but not in this project. Instead the authors ordered consumables and leaped to the construction phase where each lab station was set up and proof tested. In this way, deficiencies were noted, the lab process was recorded and lab outcomes were verified. This shake down process resulted in a few modifications to the preliminary MiniLab titles. In the Effect of Cold Work lab, mild steel specimens were not immediately available so the study was limited to FCC metals, Al and Cu. The Tensile Strength of Ceramics lab was modified to test plate glass beams. The proof testing also led to a change in the scope of student activities. In the Poisson's ratio lab, a fixture defect was uncovered that made it necessary to reuse the same specimen and fixture for all four rounds.

Instructional Materials:

The instructional materials that were prepared and posted to the course website[4] included Detailed Lab Instructions, References, and Tutorials. The quality of the instructional materials was recognized as perhaps the most critical factor to achieving the primary goal of the MiniLab round robin design project. Restated, the goal was to develop and deliver hands-on laboratory experiences that actively and cooperatively engaged all students toward the achievement of the course learning objectives *with no* traditional lecture support. The challenge was to provide, either directly or indirectly, a comprehensive set of materials that supported the participation of all students as part of a team in execution of the lab tasks including pre-lab preparation, planning, specimen preparation, testing, data acquisition and analysis, and the presentation of results.

Detailed Lab Instructions included the customary Introduction, Purpose, Procedures and References. The detailed instructions also contained a list of the particular Learning Objectives describing the targeted competencies and assessment methods. By listing the targeted outcomes and assessment methods, students know what they will be held accountable for and how this will be measured[5]. In addition, the detailed instructions contained an Overview of the lab process, a list of the major lab tasks in bulleted form. The Overview was provided to assist the team to plan and execute the lab (see Fig. 1). Finally, the detailed instructions also included a description of specific Deliverables where the Report format and content was specified. Recalling that ENGR 340 is not a lab course, the instructors chose not to burden the students with the preparation of an onerous lab report. Instead, each student was required to submit a single summary report that presented the results of the four MiniLabs in graphical and narrative forms. The content and format of the graphical presentations and narrative discussions were fully specified. The narrative content was to direct the reader to those results that were consistent with expectations, to results that deviated from the expected, then offer explanations for those deviations, if any. The instructors also elected to use the report to obtain feedback to improve the round robin activity and a self/peer evaluation of contribution (see Fig. 2). The statements of contribution were incorporated to remind students that they would be held accountable for their contribution to the total work effort.

Reference materials, cited in the Detailed Lab Instructions or posted to the course website, supplemented the textbook to cover material that would otherwise be introduced in lecture. Hertzberg[6] proved especially useful for background in the Transition Temperature Phenomenon and the Charpy Specimen lab. Ashby and Jones[7] was borrowed heavily for the Tensile Strength of Glass and the Weibull Statistic lab. Smith[8] adequately covered the Effects of Cold Work and the Poisson's ratio lab.

Learning Objective (from Effect of Cold Work MiniLab)

The learner will (**TLW**) know how to utilize PC based data acquisition systems and demonstrate this know-how by performing those tasks related to test set up, configuration, data acquisition, and transferring files on the LAN.

TLW know how to utilize PC based data processing software and demonstrate this know-how by performing those tasks related to downloading data, analysis, curve fitting and graphical presentation.

TLW know the mechanical testing processes used to determine the material properties of hardness, modulus of elasticity, yield strength, ultimate strength, and % elongation and demonstrate that knowledge by completion of hands-on test activities and by examination

TLW know and understand the effect of cold work on the mechanical properties of FCC metals through hands-on measurement and data acquisition, and will demonstrate this understanding through data analysis and the graphical presentation of results and by examination.

Overview of Lab Process (from Effect of Cold Work MiniLab)

The lab group is responsible to complete this lab in one 75-minute class session. The in-lab work process may be broken down as follows:

1. Cold work the specimens using rolling mill and digital calipers
2. Measure hardness with the Leco hardness tester
3. Measure load v. elongation using Instron servo-hydraulic test frame and extensometer
4. Repeat 1 – 3 for all specimens: 0%, 20%, 40% and 60%
5. Create and post data files to web site.

Figure 1. Detailed Lab Instructions for the Effects of Cold Work MiniLab

Two tutorials for the analysis of data were prepared and posted to the course website[4]. The .ppt presentation titled "Data Analysis to Determine E, σ_y, σ_{ult} and %-elongation at failure" was prepared for the Effects of Cold Work lab, while "Data Analysis Applying Weibull Statistics" was prepared for the Tensile Strength of Glass lab.

Delivering the MiniLab Round Robin

The round robin was scheduled for four consecutive classes in mid October. One week prior to the first round, the class of 18 was divided into four teams having four to six members. Teams also received their first round MiniLab assignment and subsequent rotation schedule. At this time in the semester, the class already completed three cooperative learning activities. In the first of these, the instructor randomly assigned students to teams. In the second, students formed their own teams and in the third, the instructor populated the teams with students having similar class standing. For this round robin activity, therefore, the instructor distributed those students with highest class standing evenly among the four teams.

Because forewarning fore arms, the class was issued several *advisories:* MiniLabs would cover new material that would not be covered in lecture. All students would be held responsible for pre-lab preparation, i.e. reading Detailed Lab Instructions and referenced material. Highly time constrained, all students must arrive prepared to participate. All students would be held responsible for submitting a report. Peer mentoring would be encouraged by requiring intra-team peer support first, inter-team peer support second and instructor support as the last resort. All data would be "parked" on the LAN to allow monitoring by instructor. All students would be tested to assess their attainment of the learning objectives.

Self/Peer Contribution/Signature Page (to be attached to Report)

Consider the totality of work involved in this mini-lab module, from the day of the first test to the completion of report preparation. How much of a contribution did you make to the total effort? Each member of the team will make and sign a statement regarding his or her contribution to the total work effort. The remaining team members will acknowledge and sign this statement. An example of such a statement follows:

My contribution to the total work effort is roughly 30%. Acknowledged by:
Timmy T signature
Signed: Ronald R Suzy Q. signature

My contribution to the total work effort is roughly 40%. Acknowledged by:
Suzy Q signature
Signed: Timmy T Ronald R signature

My contribution to the total work effort is roughly 30%. Acknowledged by:
Ronald R signature
Signed: Suzy Q Timmy T signature

Figure 2. Example of self/peer assessment of student contribution to the MiniLab work effort

Results and Feedback

Glitches

In the first round of experiments, problems arose that were related to errors and omissions in the Detailed Instructions, content deficiencies in the Instructional Materials and under estimating time for some tasks. Errors and omissions in the Detailed Lab Instructions were uncovered in the detailed setup and configuration instructions of the data acquisition systems. The four labs utilized three different DAQ systems, a National Instruments system with NI's Virtual Bench user interface, a Correlated Solutions, Inc. imaging system with CSI's VIC-2D user interface and Instron's proprietary data acquisition system with Instron's MAX user interface. The instructors addressed most of these problems "on the fly" as they arose then subsequently corrected with appropriate revisions to the Detailed Lab Instructions. Content deficiencies were also flagged in the Instructional Materials related to the image based measurement system in the Poisson's ratio lab. The first team struggled to understand 1) how digital images and image correlation "measure" displacement and 2) how lateral and longitudinal strain was *contained* in the data, i.e. the full field u(x,y) and v(x,y) displacement maps. Unable to develop a quick fix of this problem, the instructor "lectured" to explain the basics of image correlation then "coached and narrated" the lab process related to extracting the relevant data. The Detailed Lab Instructions were subsequently revised. Another concern that arose in the first round was the 45 minutes of additional time a team took to complete the Effects of Cold Work lab. There was no apparent *design* related explanation for the excessive time, nor was their any indication that our original time estimate was in error, therefore, no changes were made to the lab. Interestingly, all members of this team stayed the extra 45 minutes to complete the lab, despite assurances by the instructor that none would incur harm if they had to leave.

The remaining rounds appeared to progress smoothly and with limited input from the instructors. Following the third round, a data check by an instructor revealed an error in the Tensile Strength of Glass lab. Specifically, the load cell data was truncated to a fixed range due to a DAQ system configuration error. Checking further, it was determined that the load cell data for the first three rounds was similarly affected and therefore defective. The configuration error was corrected in time for the fourth and final round. This permitted acquisition of one complete set of data that all four teams shared, analyzed and reported.

Outcomes

Reports were submitted after a quiz was administered the fifth day of the round robin. The quiz was designed to assess 1) the knowledge and understanding of lab testing process to determine mechanical properties of materials, 2) the competency to calculate a result given a set of data and 3) the ability to interpret results to support a conclusion. The open-book open-note quiz covered the four MiniLab topics. The median, maximum and minimum scores based on a perfect score of 100 were 72, 100 and 14, respectively.

The original design called for each student to prepare and submit an individual report, however, in response to student concerns about the rushed time schedule, the instructor changed this to a team responsibility. The results presented in the team report were satisfactorily consistent with the format prescribed in the Detailed Lab Instructions and, importantly, compared favorably with those prepared independently by the instructors.

Student Feedback

Feedback received and observations made by instructors during the round robin suggested that all enjoyed the change of pace of the lab experience and actively engaged in the hands-on tasks associated with setup, specimen preparation, testing and data acquisition. While the instructors redirected numerous questions to other students for answer and resolution, most of the deflected students and the responding counterparts appeared to work through the issues constructively and cooperatively. A few students, however, were visibly uncomfortable with this feature of the round robin.

Written feedback contained in the team reports expressed appreciation for the exposure to the computer based data acquisition technologies, particularly the imaging system, image correlation and the user interface. One objected that there were too many tasks, too little time and no instruction. Another believed equipment type and quantity was inadequate. Regarding instruction, one comment expressed discomfort due to the confusion of not knowing what, why or how to do lab tasks and suggested that the instructors just tell them what to do. Another comment described the experience of relying upon another team for *know-how* then subsequently repeated that team's mistakes. Another wrote that labs were straightforward in content but handouts were obscure in their direction then criticized the data processing task of sorting through 8000 lines of data to perform the Weibull statistic.

With respect to the report deliverable, one comment recommended overhauling the reporting task and suggested that it would be more beneficial to perform the experiment then turn in the report by the next class period when the experiment was still fresh in one's mind. This would ease the work and stress load by preparing a series of small reports spread out over four weeks rather than writing one large report after all four experiments were performed. Another suggested that each student should be responsible for his or her own report thereby eliminating the scheduling conflicts associated with out of class meetings and the risks associated with team members who do not pull their own weight in the reporting task.

Through follow up class discussions, the instructors also learned that the tasks of reporting results were divided and delegated in such a way that a single team member was responsible for only one of the four lab topics and therefore predictably weak in the other three lab topics.

Reflections and the Future

The goal of this project was to actively engage students in the learning process. Was this goal achieved? Based on observation, it is the authors' opinion that the answer is a resounding yes. The team-based learning activity was tremendously effective in motivating students to engage in the task at hand, with their teammates, with students of other teams and with the instructors. These activities were physical, tactile, visual and aural in type and were directed to the execution of the lab tasks, to observing the activities of others, to questioning, to instructing, to critiquing and to socializing.

But were the learning objectives met? The quiz scores suggest the answer to that question is *no* and that there is considerable room for improvement in the demonstrated competencies. Upon reflection, we concluded that such improvement would flow from two modifications for future MiniLab activities. 1) Restore responsibility to each student for data analysis, results generation and reporting. 2) Compel students to prepare for labs in advance. Although part of the original design, the instructors conceded the individual reporting requirement in favor of single team reports, a lapse of judgment in a moment of weakness in response to the reported glitches. We believe that the unintended but predictable consequences of that decision lead to the low quiz scores. In future round robins, reporting will be an individual responsibility. Further, as suggested above in student feedback, reports would be due at the class meeting that follows the experiment. The second modification lies in designing learning tools that builds pre-lab preparation. Presently, we are considering the use of a compulsory on-line pre-lab tutorial and quiz.

In addition, the authors intend to continuously improve the instructional materials, develop a fifth lab station to further reduce team size and on-line .ppt tutorials to better describe digital imaging, image correlation and the extraction of data from the full field displacement measurements.

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Ron Goulet

Dr. Goulet, assistant professor mechanical engineering, joined the UTC engineering faculty in 1998 with over 20 years of professional experience. Following the award of B.S. in civil engineering from Northwestern University in 1976, he held various engineering positions serving the power, legal and insurance industries in Chicago and Pittsburgh. Goulet obtained his PE license in Maine in 1987 and founded Consultech, which continues to provide consulting engineering services to legal and insurance clients in New England. Dr. Goulet received a Ph.D. in Engineering from the University of New Hampshire in 1997 in the field of fracture mechanics. He held interim teaching positions with the Center for Occupational Health and Safety, CMT College, Auburn, ME and with Andover Controls Corp., Andover, MA. Dr. Goulet's primary research interest includes the application of 3D vision based displacement measurement techniques in experimental mechanics. As director of the UTC Biomechanics and Materials Testing lab, Goulet also coordinates experimental research of implanted orthopaedic constructs in collaboration with the Dept. of Orthopaedic Surgery, Chattanooga unit of the UT College of Medicine.

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