Engineering Materials Lecture and Laboratory: Cross-Disciplinary Teaching in a Small University Setting

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Abstract:

We have developed a course combining an engineering materials laboratory with a materials science lecture for a diverse population of students. By judicious selection of topic order, we are able to utilize one lecture and one laboratory for Mechanical, Civil and Biomedical Engineering students.

The basic materials lectures are in common with all groups, with the sections split for major specific topics. This means that three quarters of the term is taught on a joint basis, and three or four lectures are split.

The laboratory sections are combined for general tensile, compression, torsion, shear, bending, hardness, and fatigue testing. Sections are split for major specific topics.

The usefulness of combining courses in a small but diverse population include: more efficient usage of laboratory resources; reducing the number of separate lectures the faculty have to prepare; and teaching students how to interact with engineers in other disciplines. It is also valuable for the students to understand that the same principles govern mechanical, civil and biomedical engineering materials.

Introduction:

As a small Engineering College with limited faculty resources, we have developed a course combining an engineering materials laboratory with a materials science lecture. By judicious selection of topic order, we are able to utilize a common lecture and laboratory for students in Civil, Biomedical, and Mechanical Engineering for the bulk of the term. In view of the fact that our faculty teach the undergraduate laboratory courses (as opposed to using graduate assistants), there has been a savings of both resources and faculty load.

Small to medium sized undergraduate Engineering programs may have difficulty teaching similar topics to different populations of students. A typical course where this is an issue might be Statics and Dynamics, where Electrical and Mechanical Engineering students have different needs, but cover very similar material. With a limited faculty size and small class sizes, it is often a problem teaching the number of sections required for the various disciplines. This issue is especially true for laboratory based courses, where the space must also be coordinated.

An additional issue is the desire to consolidate courses to reduce the total student credit hours while increasing the design aspects of the program and adding "cutting edge" knowledge to the curriculum. We have done this, in part, by selectively combining courses (such as Statics and Dynamics) into a single course.

The focus of the current paper is to describe the method in which we combine our Mechanics of Materials Laboratory and Materials Science courses into one course with fewer credit hours and teach to multiple engineering disciplines simultaneously.

While this combination is ideal for a small to medium sized program with relatively small class sizes, there are aspects that would be of use to larger institutions as well. Anecdotally, the students from the different majors enjoy the opportunity to work with students outside their discipline. The concept that the techniques and fundamentals are the same for different disciplines within engineering is always a good lesson to teach. The use of the same faculty member(s) to teach the different majors in this (relatively) common subject gives continuity to the material being taught. For the professor, the chance to teach the same topic to different majors has (anecdotally) been refreshing, as each major has a different viewpoint on a given topic.

Materials Laboratory – Materials Lecture combination:

In the area of materials, we had an existing course in materials science (75 minutes twice a week), and a materials laboratory course (two hours and 40 minutes once a week). The latter had been operated as part lecture – part laboratory, with a significant amount of time spent discussing the mechanics of materials and the reasons behind the hands – on materials testing methodology and results. Depending on the term there were two – four laboratory sections, often with 6 – 8 students as opposed to the cap of 12 students.

Due to the synergy of the Materials Science course and the Materials Laboratory course, it was decided to combine the two by adding one lecture per week to the laboratory course. The 3-credit Materials Science course and the 2-credit laboratory course were combined to form a new 3-credit course. The laboratory course remained intact and a new 50-minute per week lecture was added to give the students an overview of materials science. The 3-credit Materials Science course remained an option for those students seeking a deeper knowledge in the field.

This combined course was initially taught successfully to the Civil Engineering students, while the Mechanical Engineering students and those in Biomedical Engineering remained in the traditional system of separate laboratory and materials courses. When the curricula were later changed, the Biomedical and Mechanical Engineering students were required to enroll in the combined course.

The principal logistical problem was how to teach three similar but distinct versions of the same course while minimizing the usage of faculty and facilities. The class sizes were small enough to warrant combining classes, when similar topics were taught. (Although the sections are capped at 12, the non-combined sections often had 6 – 8 students.) However, there were enough disparate topics (such as making concrete for the Civil Engineering students and Human Ligament mechanics for the Biomedical Engineering students) that a complete combination was not possible.

Based upon the needs of the three groups of students (Mechanical, Civil, and Biomedical Engineering) taking the new course, a list of lecture and laboratory topics were produced and the order shifted to produce the greatest amount of commonality.

Combined Materials Science Course and Materials Laboratory curriculum:

Upon investigation, it was determined that the bulk of laboratory and lecture material was common for the three majors (Mechanical, Civil and Biomedical Engineering). Whenever possible, the topics in each portion of the class (lecture and laboratory) were discussed in the other. For this reason, the order of topics was synchronized whenever possible.

Materials Laboratory:

Basic principles, such as how to perform a test in tension, torsion, shear and compression are common for each major. Metals and wood are common materials, and it was decided that each major should also have an understanding of cement. The major differences are that the Civil Engineering students must acquire a knowledge of concrete manufacture and testing, while the Biomedical Engineering students should become acquainted with the testing of biological materials. To make room for these topics, issues that might be of interest but were not critical were removed from these courses, as noted in the chart below. Each skipped topic is noted during the lecture portion of the laboratory but not actually tested.

During the weeks that the classes must be separated, a separate time must be arranged if the same faculty member is to cover each laboratory. In some cases, such as during the production of the concrete beam and column, an assistant can be used if the laboratories are to be held simultaneously.

It should, as always, be noted that the specific topics and order of laboratories can be altered to suit the instructors needs and goals.

Below is a chart of laboratory subjects (in chronological order) for the three courses.

Week #	Mechanical Engineering Topic	Civil Engineering Topic	Biomedical Engineering Topic
1	Introduction, Statistical Evaluation	Introduction, Statistical Evaluation	Introduction, Statistical Evaluation
2	Measurements and Hardness Testing	Measurements and Hardness Testing	Measurements and Hardness Testing
3	Tensile Testing, Metals	Tensile Testing, Metals	Tensile Testing, Metals
4	Tensile Testing, Plastics	Concrete – Consistency and Cube production	Tensile Testing, Plastics
5	Shear Testing	Shear Testing	Shear Testing
6	Torsion of Metals	Torsion of Metals	Torsion of Metals
7	Midterm	Midterm	Midterm
8	Aluminum Column Bending	Aluminum Column Bending	Aluminum Column Bending
9	Impact on Metals	ACI Beam and Column production	Impact on Metals
10	Concrete Cube Compression	Concrete Cube Compression	Concrete Cube Compression
11	Wood Compression	Wood Compression	Wood Compression
12	Wood Shear and Bending	Wood Shear and Bending	Wood Shear and Bending
13	Strain Gauges	Creep	Bone Compression, Screw Pullout
14	Fatigue	Beam and Column Testing, Fatigue	Tendon Elongation, Fatigue
15	Final	Final	Final

Materials Lecture:

The atomic and crystal structures of materials are common to the lecture portion of each class, and can be taught at one time. The same is true for the basic properties of metals, which Civil, Mechanical and Biomedical students will all need to understand. The concepts of work hardening and annealing are common, as is the introduction of phase diagrams. The study of wood as a composite material is also useful to all disciplines. While the Mechanical and Civil engineers may use this material directly, the Biomedical engineers will also find this useful as the composite nature is similar to that of long bones.

While basic information as to the make up of cement and concrete are of use to all three disciplines, only the Civil engineering students are taught this topic in depth. Asphalt is also introduced during these lectures.

To replace the above classes, the Mechanical Engineers receive lectures on polymers and ceramics, while the Biomedical Engineering students are presented topics on soft and hard tissues of the human body. The Biomedical Engineering students have the class presenting composites and polymers at the same time as the Civil Engineers, so these classes may be combined. As with the laboratories, separate times must be found for the split lectures.

As with the laboratory portion, lecture topics will vary according to the instructor. For example, the concrete portion of the lecture to the Biomedical and Mechanical Engineers might be replaced by additional lecturing on ceramics.

As noted earlier, the materials science lectures are not meant to replace the depth of knowledge of a full course. The concept is to present the student with enough information to understand the basics of the field, and be able to understand the issues involved in material selection and testing.

Below is a chart of the Materials lectures on a weekly basis:

Week #	Mechanical Engineering Topic	Civil Engineering Topic	Biomedical Engineering Topic
1	Overview, Molecular Structures	Overview, Molecular Structures	Overview, Molecular Structures
2	Molecular Structures	Molecular Structures	Molecular Structures
3	Metals	Metals	Metals
4	Metals	Metals	Metals
5	Wood	Wood	Wood
6	Wood	Wood	Wood
7	Midterm	Midterm	Midterm
8	Cement	Cement	Cement
9	Cement / Concrete	Cement / Concrete	Cement / Concrete
10	Polymers	Cement /Concrete	Bone
11	Polymers	Concrete	Bone
12	Polymers / Ceramics	Concrete	Tendons / Ligaments
13	Ceramics / Composites	Asphalt	Tendons / Ligaments
14	Composites	Composites / Polymers	Composites / Polymers
15	Final	Final	Final

Faculty load and effort:

As noted earlier, one reason for the combination of these courses is to lower the requirement for additional faculty to teach multiple sections of the course. Our institution utilizes faculty to teach all courses (lecture style and laboratory courses).

Combining the courses has lowered the redundancies, especially during the laboratory section. Of thirteen laboratory assignments each for the three majors (39 total sessions if completely separate), there are only eight (four Civil Engineering, two Mechanical Engineering and two Biomedical Engineering) that require separate teaching. Except for two laboratories during which the Civil Engineers are mixing cement and concrete, the split laboratories are taken during the last two weeks of the term.

Combining the majority of the materials lectures has also proven to be a savings of faculty effort, especially in the early portion of the term. The first half of the course, where the fundamentals of molecular and crystal structures are taught, is common. Personal experience has suggested that many students have difficulty with these issues, so being able to teach all the students at the same time makes it easier to concentrate on the problems they are having.

Being able to teach the mechanical properties of metals, wood and cement at the same time to each group has also been an advantage for the faculty in terms of preparation time. There is also the combination of teaching composites and polymers to the Civil and Biomedical Engineering students. While the greater depth taught to the Mechanical Engineers in these areas would be of use to the other students, not everything can be taught to everyone considering the time constraints.

There are more separate lectures in the second half of the course than separate laboratory sections, as materials and properties specific to each discipline are taught. As the lectures are 50 minutes per week, this is not nearly the problem as the two hour 40 minutes laboratory sessions.

<u>Anecdotal benefits for students:</u>

The manner in which this course is being taught is a recent change, so it is yet early to evaluate the true benefits to students. Written course evaluations have been uniformly positive. Students completing the course feel that they have a solid understanding of the material. Discussions with students who have completed the course have been quite favorable. The students feel that they are prepared for later courses which discuss materials.

The students seem to enjoy being in the same lecture and laboratory with students from other majors. The concept of commonality among the majors has been emphasized. The students have also enjoyed hearing of the issues in the other disciplines from both the faculty and students, something not possible in split courses. There have been comments from students that, although not directly related to their own major, they would like to perform some of the laboratories undertaken by the other groups.

To date, we have had no reports from students that the limited nature of their materials lectures has adversely affected their graduate studies, job performance or performance in the Fundamentals of Engineering examination. As noted earlier, students interested in obtaining a greater knowledge of materials are encouraged to take the Physics Department course in Materials Science.

A final benefit for students lies in the class size. We generally cap the laboratory sections at 12 students (with the possibility of adding students to a maximum of sixteen). The old system generally included 1 – 2 more laboratory sections per term with frequent class sizes of 6-8 students. Since laboratory reports are written in groups, a larger class size translates to larger groups and thus less work per student.

Discussion and Conclusions:

As a small university with small class sizes and limited faculty and resources, we have found that combining students from Mechanical, Civil and Biomedical Engineering degree programs in a consolidated materials science lecture and materials laboratory has been an efficient usage of faculty and facilities.

Combining the courses has allowed fewer faculty to cover the course without overloading. With the same topics being taught to three populations of students at the same time, only one class preparation is required. The number of required separate lectures and laboratories are small, so the increase in workload is not nearly that of a separate course.

Combining the students also greatly reduces the burden on facilities, where only a single laboratory is available for use. Combining what might be three small classes into one or two that fill the facility reduces waste and becomes more economical.

Our experience to date has been positive with this system. Refinements are constantly being made, and will continue to be done as we receive more feedback from past students.

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