June 2005

Development of Project-Based Introductory to Materials Engineering Modules

Stacy Gleixner
San Jose State University, stacy.gleixner@sjsu.edu

Elliot Douglas
University of Florida

Olivia Graeve
University of Nevada, Reno

Hilary Lackritz
San Jose State University

Laura Demsetz
College of San Mateo

See next page for additional authors

Recommended Citation
Stacy Gleixner, Elliot Douglas, Olivia Graeve, Hilary Lackritz, Laura Demsetz, and Amy Moll. "Development of Project-Based Introductory to Materials Engineering Modules" *ASEE Annual Conference* (2005): 10.473.1-10.473.12.

AC 2005-1201: DEVELOPMENT OF PROJECT-BASED INTRODUCTORY TO MATERIALS ENGINEERING MODULES

Amy Moll, Boise State University

Elliot Douglas, University of Florida

Hilary Lackritz, Purdue University

Laura Demsetz, College of San Mateo

Olivia Graeve, University of Nevada-Reno

Stacy Gleixner, San Jose State University

Development of Project-Based Introductory to Materials Engineering Modules

S.H. Gleixner[1], E. Douglas[2], O. Graeve[3], H. Lackritz[1], L. Demsetz[4], A. Moll[5]

[1]Department of Chemical and Materials Engineering, San Jose State University/ [2]Department of Materials Science and Engineering, University of Florida/ [3]Metallurgical and Materials Engineering, University of Nevada, Reno/ [4]College of San Mateo/ [5]Mechanical Engineering, Boise State University

Abstract

This paper will discuss the progress of curriculum development under an NSF, CCLI-EMD sponsored work, "Development of Project-Based Introductory to Materials Engineering Modules" (DUE # #0341633). A multi-university team of faculty are developing six lecture and three laboratory modules for use in Introductory to Materials courses. This course is required by most engineering programs in the U.S., with an annual enrollment of 50,000 students. This freshman/ sophomore class is an ideal place to excite students about their engineering majors and expose them to engineering design experiences. PRIME Modules, Project Based Resources for Introduction to Materials Engineering, are being developed that utilize modern materials science and engineering technologies and proven education methodologies of active learning and open ended projects.

The classroom component of the course will be made up of "Applied Engineering Content" (AEC) Modules. These three to four week modules will cover a set of the fundamental learning objectives for the course within the context of a current innovation in materials engineering. AEC modules on biomaterials, sports materials, nanomaterials, materials for communications, alternative energy sources, and aerospace materials will be created. The modules will include learning objectives, active learning exercises, lecture notes, industry relevant demonstrations and examples, open ended design problems, and assessment tools.

"Engineering Project Lab" (EPL) modules will be developed to expose students to different roles that materials engineers have in industry: failure analysis, materials selection for product design, and process optimization. Each laboratory module will cover four to five lab sessions. The curriculum will include hands-on learning exercises with the equipment and material and an open ended project. Each module will have learning objectives and assessment tools created along with the lab exercises.

The overall goal is to develop a diverse set of modules such that faculty could choose the modules based on the learning objectives appropriate to their class and the technologies of interest to their students. Development work began in the summer of 2004. This paper will explain the full plan for the three year project as well as provide detail on the development work completed in this early stage.

Background

Throughout history, major advancements in technology have been marked by materials: from the Stone Age to the Bronze Age to the Silicon Age. Each new technical innovation has required discoveries in materials to surmount barriers and limitations. This leads to an overlap between materials science and almost every other engineering field. Electrical engineers use materials science and engineering to produce computer chips, lasers, and superconductors. Structural materials such as concretes for roads and metals for buildings and bridges are crucial to civil engineers. Mechanical engineers must consider the strength and long term reliability of the materials used in their designs. Light weight, strong materials are continuously researched and tested by aerospace engineers. Biomedical engineers investigate alternative materials for transplants, artificial limbs, and surgical tools.

For this reason, most engineering programs require their students to take an introductory materials class. This includes community colleges with engineering transfer programs. In the U.S. alone, the “Introduction to Materials” course enrolls over 50,000 students a year.[1] The primary goal of the class is to provide a foundation in materials science and engineering that the students can build upon in their major classes and future careers.

The curriculum and lab content for the existing “Introduction to Materials” course taught at San Jose State University is given in Table 1. Researching the equivalent course at other institutions showed that most courses cover the same material in a similar format. In a search of online syllabi, the first twenty syllabi investigated all covered at least 80% of the lecture topics in Table 1. This is significant in that the modules could have widespread applicability because most courses cover the same fundamental content.

Table 1: Outline for San Jose State’s traditional “Introduction to Materials” course.

Lecture Topics	Lab Topics
Atomic Structure & Bonding	Crystal Models & Defects
Crystal Structure	Hardness Test
Imperfections	Fracture Test
Diffusion	Tensile Test
Mechanical Properties	Cold Working
Strengthening Mechanisms	Pb/Sn Phase Diagram
Phase Diagrams	Tempering of Steel
Electrical & Magnetic Properties	Ductile to Brittle Transitions
Ceramics	Corrosion
Polymers	Polymer/ Composites
Composites	Electrical & Magnetic Properties

PRIME modules, Project Based Resource for Introduction to Materials Engineering, are being developed in which students are immersed in the interdisciplinary nature of the field. Students will learn the role materials have in current innovations. The interaction between materials engineers and other engineers and scientists will be emphasized. The modules will teach and assess communication, teamwork, and design skills. The overall objectives of the project are to modernize the content and delivery of the introductory materials science and engineering course through the following:

- Develop six classroom modules that teach the fundamental principles of materials science and engineering through modern technologies
- Develop three laboratory modules that use open ended projects to emphasize the roles of materials engineers in industry
- Solicit feedback on the modules from formal partnerships with industry and community college representatives
- Beta test the modules at varied institutions including community colleges, undergraduate teaching colleges, and research universities
- Assess the modules for their impact on student learning as well as their ease of adaptability by other institutions

Two types of modules will be developed, each will teach the fundamentals of materials science and engineering in an applied setting alongside professional skills such as teamwork, communication, and design. The classroom component of the course will be made up of "Applied Engineering Content" (AEC) Modules. These three to four week modules will cover a set of the fundamental learning objectives for the course within the context of a current innovation in materials engineering. For example, a module in biomaterials would teach the fundamentals of mechanical testing, polymers, and ceramics using the example of hip implants. The AEC modules will include learning objectives, active learning exercises, lecture notes, industry relevant demonstrations and examples, open ended design problems, and assessment tools. A total of six AEC modules on different modern materials science and engineering technologies will be created. The goal is to develop a diverse set of modules such that faculty could choose the modules based on the learning objectives appropriate to their class and the technologies of interest to their students. Using a range of different technologies will increase the likelihood of engaging a diverse student population.

"Engineering Project Lab" (EPL) modules will be developed to expose students to different roles that materials engineers have in industry: failure analysis, materials selection for product design, and process optimization. Each laboratory module will cover four to five lab sessions. The curriculum will include hands-on learning exercises with the equipment and material and an open ended project. Each module will have learning objectives and assessment tools created along with the lab exercises.

The modular format of the curriculum will allow the material to be easily adapted to other institutions and even other courses. Curriculum will be developed at one institution and beta tested at another. The testing allows verification of the utility and adaptability of the curriculum to multiple universities. The institutions involved in the development and beta testing represent a diverse set of engineering schools, including primarily teaching universities, research universities, and community colleges. They also represent diverse student populations and different campus cultures. For example, San Jose State University's College of Engineering is over 70% minority students and over 65% transfer students. 40% of Boise State University's freshmen are over 24 years of age. The success of the modules at all of the institutions involved will be assessed to guarantee the widest applicability of the modules.

Applied Engineering Content Modules

The fundamental principles of materials science and engineering will be presented in "Applied Engineering Content" (AEC) modules that center around a modern technology. The use of relevant, industry examples will expose freshman and sophomores to realistic engineering situations. The modules will accurately inform students about engineering and excite them about recent technological advances. By tying the fundamental material to technologies, students will obtain a "bigger picture" view of the field. Placing the "Introduction to Materials" curriculum in a framework where the students can see its relevance to their interests and the world around them should increase their understanding and retention of the material.[2] Balancing the concrete and abstract content will cater to different learning styles, especially benefiting global learners who suffer in traditional forms of the class that do not emphasize the "bigger picture".[3] Cabral et al showed that placing the fundamental material within the context of an applied situation increases students motivation to learn.[4]

Table 2 lists the proposed AEC modules and outlines the fundamental concepts they cover. Faculty teaching a complete introduction to materials course would choose three or four modules that together cover the complete set of learning objectives. This gives faculty the flexibility to choose technologies of interest to their student bodies. Discrete modules could also be used in other engineering courses such as "Introduction to Engineering", "Materials Processing", or "Strength of Materials".

Table 2: The curriculum covered in the Applied Engineering Content Modules and the Engineering Project Labs.

	Atomic Bonding	Crystal Structure	Defects	Diffusion	Mech Prop	Elec Prop	Mag Prop	Phase Diagrams	Metals	Ceramics	Polymers	Composites	Corrosion	Materials Processing	Mechanical Testing	Materials Analysis	Elect. Testing
AEC Modules																	
Biomaterials					X				X	X	X			X			
Nanotechnology				X				X	X	X				X			
Sports Materials			X		X						X			X			
Computers & Communication	X	X		X		X	X										
Aerospace & Structural Composites	X			X	X						X	X		X			
Alternative Energy Sources	X	X	X			X							X				
EPL Modules																	
Process Optimization								X						X	X	X	
Failure Analysis								X					X		X	X	X
Materials Selection											X	X		X	X		

The development is divided between the multi-university team of faculty. Dr. Stacy Gleixner at San Jose State will develop AEC modules on materials for computers and alternative energy sources. Dr. Douglas at the University of Florida will develop AEC modules on biomaterials and aerospace composites. AEC modules on sports materials and nanotechnology will be developed by Dr. Graeve at University of Nevada-Reno. A formal industry advisory board is being set up to consult on the content of the modules, assuring they are technically correct and relevant.

From the onset, the modules will be developed with a consistent format and with portability and wide scale dissemination in mind. Figure 1 is a schematic of the components that would make up one AEC module. The components of each module will be carefully constructed factoring in the wealth of information that has been published in recent years on engineering education, including developing outcomes based classes, effectively using active learning exercises in classes, and teaching teamwork and communication skills.[5]

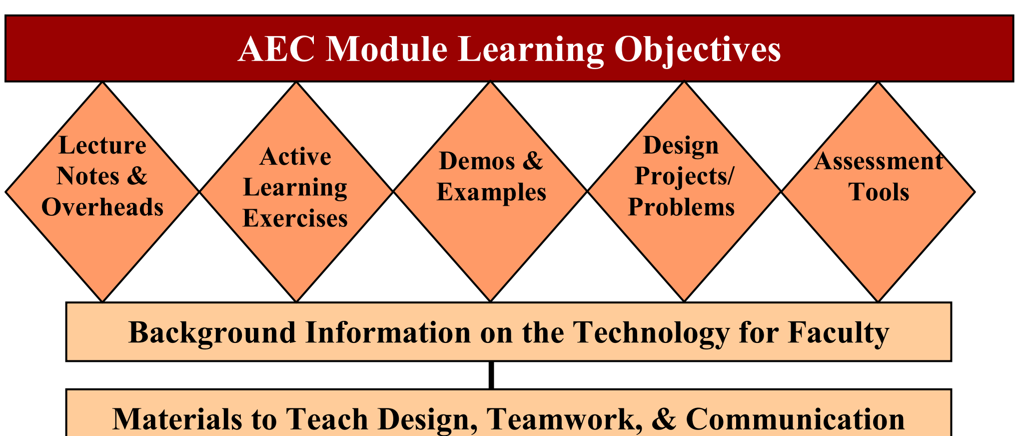

Figure 1: Schematic of the components in each Applied Engineering Content module.

The first step in the creation of the modules will be to develop learning objectives using Bloom's taxonomy.[6] The learning objectives covered in traditional Introduction to Materials courses at five institutions were compared. Using these objectives, a survey was created for the faculty of other engineering departments at the host institutions. The goal of the survey is to evaluate which learning objectives are critical to which majors. This will ensure that the modules will be useful to their student audiences. It will also provide information on which modules to use for a given student population. Table 3 lists the goals and some sample learning objectives for the six modules.

Table 3: Goals and sample learning objectives for the Applied Engineering Content modules.

Biomaterials (Developed at University of Florida): Goal: At the end of this module, students will understand how the choice of different materials impacts the performance and mechanical properties of a hip implant. Objectives: Students will be able to: • Describe the materials used for a hip implant. • Describe the different properties that are of importance for a hip implant. • Evaluate the advantages and disadvantages of different materials used in a hip implant. • Specify the appropriate materials to be used for a biomedical implant, given design constraints.
Materials for Data Storage (Developed at San Jose State): Goal: At the end of this module, students will understand the structure and operation of magnetic hard drives and non-volatile Flash memory as well as the electrical and magnetic properties of the materials involved. Objectives: Students will be able to: • Describe the materials used in Flash memory and magnetic hard drives. • Calculate the critical electrical and magnetic properties. • Evaluate the impact of processing variables on the storage density of the devices. • Choose the materials system for a memory cell given design constraints.
Aerospace and Structural Composites (Developed at University of Florida): Goal: At the end of this module, students will understand the materials, processing, and mechanical testing used in aerospace and structural composites. Objectives: Students will be able to: • List the materials used in aerospace and structural composites. • Describe the processing techniques used for composites. • Compare the effect of different materials on the mechanical properties of the composites. • Design a composite system to meet given property and cost constraints.
Nanotechnology (Developed at University of Nevada, Reno): Goal: At the end of this module, students will understand the materials and processing used for ceramic nanomaterials used to make solid oxide fuel cells. Objectives: Students will be able to: • Describe the processing techniques for ceramic and metal nanomaterials. • Determine the stable phase of a ceramic or metal from a phase diagram. • Compare the bulk processing of metals and ceramics with those used in nanotechnology. • Optimize a process flow for a nanomaterial given design constraints.
Alternative Energy Sources (Developed at San Jose State):

Goal: At the end of this module, students will understand how solar cells and batteries operate and the importance of crystal structure and defects in these devices. Objectives: Students will be able to: • Draw the crystal structure of materials used in solar cells. • Describe the impact of defects on the efficiency of a solar cell. • Calculate the voltage potential of a battery given the material system. • Design an energy storage device based on optimizing cost, efficiency, reliability, and environmental impact.
Sports Materials (Developed at University of Nevada, Reno): Goal: At the end of this module, students will understand how the structure and processing of polymers critical to the manufacturing of skis and snowboards. Objectives: Students will be able to: • Define a polymer and describe some used in skis and snowboards. • Describe the mechanical properties of importance to polymers. • Evaluate the applicability of certain processing techniques on polymers for skis and snowboards. • Adapt a polymer processing technique used for skis to another sports application.

Lecture notes and overheads or PowerPoint slides, active learning exercises, in-class examples and demonstrations, and assessment tools will developed based on the learning objectives. Each AEC module will involve a team based design project that will constitute most of the homework. The project will be open ended but will guide students through learning the basic material as well as accomplishing the end design goal. Support material for faculty including review articles and a suggested reading list will be assembled to improve the portability of the modules and ensure that faculty with diverse backgrounds will be comfortable using the modules.

Currently, AEC modules have been developed on nanomaterials (by Dr. Graeve at University of Nevada, Reno), biomaterials (by Dr. Douglas at University of Florida), and materials for data storage (by Dr. Gleixner at San Jose State University). These modules will be utilized and assessed in the spring semester by the faculty who developed them. They will be modified based on the assessment over the summer and beta-tested by other faculty in the fall. The remaining three modules will be developed in the 2005-2006 academic year.

Engineering Project Lab Modules

Engineering Project Lab (EPL) modules will be developed to expose students to engineering experiences similar to those found in industry. The students would complete three design projects that highlight different roles of materials engineers: failure analysis, process optimization, and materials selection for product design. The materials science and engineering topics covered in each module are outlined in Table 4. The EPL labs on failure analysis and materials selection will be developed jointly by San Jose State and College of San Mateo. The EPL module on process optimization will be developed by Dr. Moll at Boise State. (The development of this lab module is not funded by NSF.)

Each lab will have the same format, consisting of learning objectives, small labs to teach content and equipment specific to those learning objectives, open ended design projects, and assessment tools, Figure 2. Table 4 lists examples of the small teaching labs and open ended team project for each EPL. Support material will also be provided for faculty that details examples of how each engineering role is used in industry. When adapting labs to other institutions, the equipment is usually the most constraining factor. Therefore, the modules will be developed using standard materials testing and analysis equipment available at most universities. However, suggested alternatives will be developed for use at institutions that do not have the needed equipment. This is particularly critical to ensure the utility of the modules at smaller teaching colleges and community colleges. The materials selection module is under development and will be utilized and assessed in Fall 2005. The other modules will be developed in the 2005-2006 academic year.

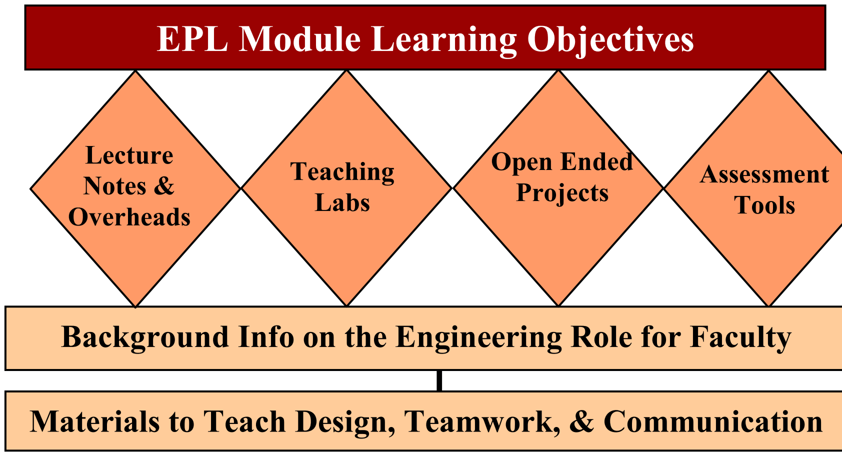

Figure 2: Schematic of the components in each Engineering Project Lab module.

Table 4: Engineering Project Labs to highlight the roles materials engineers have in industry.

Teaching Labs	Open Ended Project
Failure Analysis Lab Module (developed at College of San Mateo Community College)	
• Metallography • Materials Analysis • Phase Diagrams • Corrosion	• An engineer for a company that makes biomedical stents studies how corrosion degrades the mechanical properties of the device.
Optimizing a Process Lab Module (developed at Boise State University)	
• Cold working • Tempering • Materials Analysis • Mechanical Testing • Statistical Process Control	• An engineer at an integrated circuits manufacturer designs the manufacturing process for metal wires based on optimum mechanical strength, reliability, and conductivity.
Materials Selectrion/ Product Design Lab Module (developed at San Jose State University)	
• Polymer and composite processing • Hardness and tensile tests	• An engineer at car company tests a range of materials for their mechanical properties and reliability, choosing the best option for a new hybrid car.

<u>Support Material</u>

In order for the students to be successful in the active learning exercises and team based design problems, skills in teamwork, project management, and communication need to be taught. Extensive resources for this exist in the engineering education literature and online. The PRIME modules make use of these resources through websites for both faculty and students. These websites link faculty and students to the best resources for each topic. Worksheets, homework problems, and in-class exercises have been developed to guide students through these topics.

Evaluation Plan

Assessment of the modules will take place on several levels. First, the success of the modules in teaching students the fundamental learning objectives will be assessed. This will be done through traditional methods of evaluating student performance on projects, in-class exercises, homework, tests, etc. The module development will include development of these assessment tools.

The impact on students' opinions of engineering in general and materials in specific will also be assessed through pre and post surveys done in the class. These surveys will be compared with results of the same survey given in traditional Introduction to Materials courses to determine if the open ended project modules have a different impact on student interest.

Adaptability of the modules will be assessed when they are beta tested by other universities. Surveys will be used to document the satisfaction of the faculty with the content and format. Differences in satisfaction may correlate with institute type due to differences in backgrounds of the students and faculty, campus cultures, and laboratory resources. The assessment data will be used when revising the modules before publication.

Summary

An introductory materials science and engineering course is required by most engineering programs in the U.S., and such courses are offered by materials science and engineering departments, as well as by other engineering departments and engineering transfer programs at community colleges. This freshman/ sophomore class would be an ideal place to excite students about their engineering majors and expose them to engineering design experiences. A curriculum that utilizes modern materials science and engineering technologies and proven education methodologies of active learning and open ended projects would have widespread applicability and could make a significant impact on engineering education.

PRIME Modules, Project Based Resources for Introduction to Materials Engineering, are being developed that utilize modern materials science and engineering technologies and proven education methodologies of active learning and open ended projects. The classroom component of the course will be made up of "Applied Engineering Content" (AEC) Modules. These three to four week modules will cover a set of the fundamental learning objectives for the course within the context of a current innovations biomaterials, sports materials, nanomaterials, materials for communications, alternative energy sources, and aerospace materials. The modules will include learning objectives, active learning exercises, lecture notes, industry relevant demonstrations and examples, open ended design problems, and assessment tools. "Engineering Project Lab" (EPL) modules will be developed to expose students to different roles that materials engineers have in industry: failure analysis, materials selection for product design, and process optimization. Each laboratory module will cover four to five lab sessions. The curriculum will include hands-on learning exercises with the equipment and material and an open ended project. Each module will have learning objectives and assessment tools created along with the lab exercises. The PRIME modules also include support material for faculty and students on active learning, teamwork, project management, and communication. The modules will be beta-tested at a range of institutions to assure portability and utility across the academic spectrum.

References

1. Private Communication, Jonathan Plant, Senior Sponsoring Editor: Mechanical, Materials & Aerospace Engineering, Mc-Graw Hill (support letter attached)
2. B. Gross Davis, Tools for Teaching, Jossey-Bass (2001).
3. R.M. Felder, "Reaching the Second Tier: Learning and Teaching Styles in College Science Education", *J.of Coll. Sci. Teaching,* 23(5), p. 286 (1993). http://www.ncsu.edu/effective_teaching/Papers/Secondtier.html
4. A. Cabral, R. Viau, and D. Bedard, "Situated Learning and Motivation Strategies to Improve Cognitive Learning in CE", *Procs. ASEE Annual Conference*, (1997).
5. R.M. Felder, D.R. Woods, J.E. Stice, and A. Rugargci, "The Future of Engineering Education II: Teaching Methods that Work," *Chem. Eng. Educ.*, **34(1)**, p. 26 (2000). http://www.ncsu.edu/effective_teaching/Papers/Quartet2.pdf
6. B.S. Bloom, Taxonomy of Educational Objectives, Longman, (1984).

Biographies

STACY GLEIXNER is an Assistant Professor in the Department of Chemical and Materials Engineering at San Jose State University. She teaches courses on introductory materials engineering, electronic materials, solid state kinetics and thin film deposition. Prof. Gleixner has an active research program in microelectronics and micro electro mechanical systems (MEMS). She can be reached at gleixner@email.sjsu.edu.

ELLIOT DOUGLAS is an Associate Professor in the Department of Materials Science and Engineering at University of Flordia. He teaches courses on materials chemistry and polymer science. Prof. Douglas has an active research program in bioduplication, thermosets, and engineering education. He can be reached at edoug@mse.ufl.edu.

OLIVIA GRAEVE is an Assistant Professor in the Department of Metallurgical and Materials Engineering at University of Nevada, Reno. She teaches courses ceramics, nanomaterials, and materials characetrization. Prof. Graeve has an active research program in synthesis of ceramic nanomaterials and the computer modeling of grain growth. She can be reached at oagraeve@unr.edu.

HILARY LACKRITZ is a lecturer in the Department of Chemical and Materials Engineering at San Jose State University. She teaches courses on introductory materials engineering, solid state kinetics, and materials characterization. She has a joint research program with NASA involving innovative materials characterization techniques for biomaterials. She can be reached at hilary.lackritz@sjsu.edu

LAURA DEMSETZ is a Professor of Engineering at the College of San Mateo. She teaches courses in introduction to engineering, engineering graphics, and statics. She can be reached at demsetz@smccd.net.

AMY MOLL is an Assoicate Professor in Mechanical Engineering and the Interim chair of Materials Science and Engineering at Boise State University. She teaches courses in introductory materials engineering. Dr. Moll's research interests are focused in the areas of processing and characterization of microelectronic materials with an emphasis on microelectronic packaging. She can be reached at amoll@boisestate.edu.