AC 2007-1852: PRIME MODULES: TEACHING INTRODUCTION TO MATERIALS ENGINEERING IN THE CONTEXT OF MODERN TECHNOLOGIES

Stacy Gleixner, San Jose State University

STACY GLEIXNER is an Associate 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, University of Florida

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, University of Nevada-Reno

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.

PRIME Modules: Teaching Introduction to Materials Engineering in the Context of Modern Technologies

Abstract

This paper discusses 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 is developing five lecture 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 real world engineering experiences. PRIME Modules are being developed that teach the fundamentals of a traditional introduction to materials engineering course in the context of modern technologies. The key objectives of the modules are to show students how the fundamental principles are interrelated to each other and applied to modern applications.

Five classroom modules have been developed that each focus on a different technology. Each classroom module contains background resources for faculty on the technology, lecture notes including instructor notes, active in-class exercises, homework problems, and a team project. The project is designed to be open-ended to engage the students more deeply in the modern technology covered by the module. There is a microelectronics module where students learn about the fundamentals of electronic and magnetic properties. The teaching of these fundamentals is done within the scope of learning about options for non-volatile memory (such as Flash and M-RAM). There is a module focusing on alternative energy where students study solid oxide fuel cells and the ceramic nanomaterials used to fabricate them. While exploring this emerging application, students learn the basics of ceramics, defects, and phase diagrams. Structure, processing, and mechanical properties of polymers and composites are taught in a module on fiber reinforced plastics used for civil infrastructures. A biomaterials module on stents teaches students about crystallography, mechanical properties and strengthening mechanisms of metals, and phase diagrams. In a sports materials module, students learn about the processing and mechanical properties of polymers and composites within the context of materials used for skis.

Initial assessment on the modules indicates that most students enjoy the PRIME module class more than their other engineering classes and self-report that they learn more than in their other engineering classes. Assessment of student learning by the Materials Concept Inventory Quiz indicates that students learn basic materials principles at the same level as a traditional course. Feedback from students' written surveys indicates they value seeing the material in the context of an application and the repetition of topics. Students also comment positively on the curriculum aspects of the module including the lecture notes, active class exercises, and extensive support on the website. While most of the feedback from students is positive, some students do not favor the module format. Their primary reasons are that they feel the projects introduce extra work and they are bothered by not following the textbook in sequential order.

Background

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 topics covered in this course are relatively consistent at schools across the nation. This is reflected in the similarities between introductory texts utilized for the course. In a traditional version of this course, each major topic, represented by a chapter in an introductory text, is covered in a week or two of class. While this methodology is effective at teaching students the basics of materials science it does not adequately expose the students to how all the fundamental topics are interrelated. Students also do not get a strong sense of the role materials engineering has in developing and manufacturing many modern technologies.

PRIME modules have been developed to teach the fundamental principles covered in a typical introductory materials course within the context of modern engineering technologies. The same fundamental principles of materials science and engineering that are typically delivered in a traditional model of an Introduction to Materials course are taught. However, the fundamental topics are arranged in modules that focus on a modern technology. The main goal is to show the interrelation between the fundamental topics, that is how several different phenomena contribute to a technology.

Students are exposed to exciting technologies and are made aware of the important role materials science plays in those technologies. Through team projects, the students are also encouraged to explore their own interests and discover the overlap between their engineering major and materials science. By framing the coursework so that the students can see its relevance to their interests and the world around them, the students' understanding and retention of the material should increase.[2] Balancing the concrete and abstract content should 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] Each lecture module has an open ended project that student teams work on throughout the course of the module. The project is integrated into each module in order to increase student ownership of their learning and to deepen students' application of the fundamentals they are learning.[5]

Overview of Module Format

The PRIME modules are designed to be utilized within the framework of a traditional lecture-only class. Table 1 lists the technologies covered by the modules along with the fundamental materials engineering principles taught in that module. While each individual module emphasizes how different fundamental topics are critical to a certain application, topics are also repeated between modules. For example, students explore crystallography and defects within the context of memory metals used for biomaterials, ceramics used for solid oxide fuel cells, and silicon in non-volatile memory devices. This repetition throughout the semester is different from a traditional course in which the topic is covered in one chapter and then not often revisited. The exposure to fundamental topics in different contextual settings allows the students to view the principle from different perspectives and to form a higher level understanding of it.

Table 1: PRIME Modules to teach fundamental materials principles in the context of modern materials technologies.

Field	**Application**	**Atomic Struct. & Bonding**	**Crystal Structure**	**Imperfections**	**Diffusion**	**Mechanical Properties**	**Strengthening Mechanisms**	**Phase Diagrams**	**Ceramics**	**Polymers**	**Composites**	**Electrical Properties**	**Magnetic Properties**
Biomaterials	Biomedical Stent	✓	✓	✓		✓	✓	✓					
Alternative Energy	Solid Oxide Fuel Cell		✓	✓	✓			✓	✓				
Sports Materials	Skis					✓				✓	✓		
Civil Infrastructure	Fiber Reinforced Polymer Bridges				✓	✓				✓	✓		
Microelectronics	Non-volatile Memory Devices	✓	✓	✓								✓	✓

Each PRIME module is designed to take 3-5 weeks of class time. To date, the modules have been used in multiple introductory to materials engineering courses where faculty have used anywhere from 1-4 modules per semester. The modules have also been used in polymer and ceramics courses. Table 2 gives a possible schedule for implementing the modules into a 16-week semester for an Introduction to Materials Engineering course.

Table 2: Implementation of PRIME Modules into a 16-week Introduction to Materials Engineering course.

Week	**Module**	**Topic**
1	Biomaterials	Intro to Biomaterials and Atomic Bonding
2	Biomaterials	Crystal structure
3	Biomaterials	Defects & Mechanical Properties
4	Biomaterials	Strengthening Mechanisms
5	Biomaterials	Phase Diagrams
6	Alternative Energy	Intro to fuel cells, Ceramic Structures
7	Alternative Energy	Ceramic Defects & Processing
8	Alternative Energy	Diffusion
9	Alternative Energy	Ceramic Phase Diagrams
10	Civil Infrastructure OR Sports Materials	Polymer Structures

Week	Module	Topic
11	Civil Infrastructure OR Sports Materials	Mechanical Properties of Polymers
12	Civil Infrastructure OR Sports Materials	Composites
13	Microelectronics	Intro to Memory devices/ Electrical Properties
14	Microelectronics	Semiconductor Devices
15	Microelectronics	Magnetic Properties
16	Microelectronics	Magnetic Properties

The modules are designed to be portable to other faculty and universities. To accomplish this, a host of resources have been developed for each module. These are detailed in Figure 1.

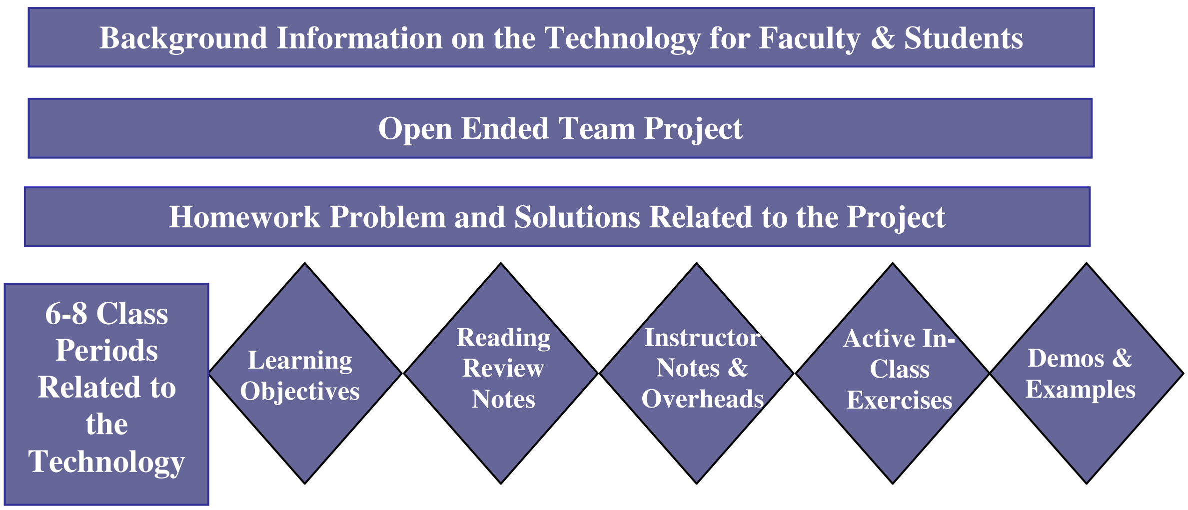

Figure 1: Overview of content developed for each PRIME Module.

Each module has a brief document describing the technology, its relation to materials science and engineering, and current research issues related to the field. The background resource also includes a set of references for the faculty to gain a deeper understanding of the technology.

There is a team-based project that can be accomplished within the framework of a lecture only class. The project allows students to explore the technology more deeply and apply the basic introduction to materials concepts they have been learning in class. The deliverables vary with the modules and include technical posters, product brochures, engineering memos, and online tutorials. They are designed to be fun and different from typical classroom assignments. The teams for the projects are assigned at the beginning of the semester. The 3-4 member teams are composed of a mix of engineering majors with similar, self-reported grades on their pre-requisite classes. The goal of this team make-up is to create teams where differing engineering majors bring different perspectives but similar levels of academic expertise. This hopefully minimizes the likelihood of one team member to dominate or to not contribute. At the start of the semester, the teams participate in a Materials Scavenger Hunt in the engineering building as a team building exercise.[6] Every student is given a teamwork evaluation form that has them rate the performance of themselves and their teammates using both a numerical scale and written comments. They are encouraged to fill this out over the course of the project. Their individual grades are reduced if they do not submit a completed teamwork evaluation form with the project. Upon completion of the project, students have the option to quit their team or fire a team member. It is observed that about 75% of the teams choose to remain intact for all the projects. .

Each class period in the module has learning objectives and reading assignments the students need to do before class. The reading assignments utilize a traditional materials science text.[7] The module website has reading review notes for each reading assignment. This is a list of main topics and review questions to highlight the relevant parts of the text. The students can view these online before the class period.[8]

PowerPoint lecture notes along with instructor notes have been developed. The lecture notes provide details on the fundamental materials principles, using the modern technology as an example. The lecture notes are structured in a clean, concise format that has been shown to improve student learning.[9] The students can view the lecture notes online.[8] The instructor notes include suggestions for demonstrations and places to utilize informal active learning in the classroom (such as surveying the students or having a quick "Pair & Share").[2] The PowerPoint lecture notes are utilized as a complement to the instructor's own writing on the board and interaction with the class.

For each class period, there is an active in-class exercise designed to engage the students through brainstorming or calculation. These in-class activities challenge the students to apply the introductory materials engineering concept they are learning about to the technology. The exercises use 3-4 member groups based on where the students are sitting in lecture (not necessarily their project team). This group dynamic is chosen solely for the sake of organizational time. Each group is given one copy of the question. The worksheet details the role of each group member (typically a leader, recorder, and spokesperson). The exercise is designed to take about 10 minutes of class time. During that time, the instructor circulates the room answering individual group's questions. Upon completion of the activity, groups are called on to discuss their questions and solutions. The solutions are posted online after class.[8] The modules also have a number of homework problems designed to teach the basic introduction to materials concepts within the context of the technologies.

Overview of Technologies

<u>Biomaterials Module: Self-expanding Stents</u>

In the biomaterials module, students learn about NiTi (Nitinol) stents. These biomedical devices are used to permanently scaffold arteries. NiTi is a shape memory alloy that undergoes a phase change from austenite (B2, CsCl structure) to martensite (monoclinic). The phase change can be temperature or stress induced. There is a volume change between the two phases. There is also a change in the mechanical properties of the two phases with the martensitic phase exhibiting superelastic properties. In a self-expanding stent, the superelasticity is utilized. A stent is placed in the body with a surgical tool that crimps the stent shut. Due to the crimping, the stent is in the martensitic, superelastic phase. When released in the body, the stent expands dramatically. The superelasticity allows for the large expansion of the stent upon release and the continual flexing of the stent over its lifetime in the artery. In order to stabilize the elastic region, the Nitinol is cold worked. Also, as part of the processing, the metal goes through a high temperature anneal, quench, and then temper. This thermal processing is done to control the extent of Ni rich precipitates that form in the metal, which in turns controls the temperature at which the memory metal undergoes the martensite phase change.[10] In order to understand this technology, students learn about metal crystal structure and defects, mechanical properties, stress strain diagrams, strengthening mechanisms, and phase diagrams. Details of this module, including class by class learning objectives have been published previously.[11]

Alternative Energy Module: Solid Oxide Fuel Cells

In the alternative energy module, students learn about ceramics and nanomaterials within the context of solid oxide fuel cells. A solid oxide fuel cell generates current and the harmless by-product of water from a hydrogen fuel source and air. The air is taken in on the cathode side and heated in order to break it down into to O^{2-} ions. The O^{2-} ions diffuse across a solid electrolyte to an anode. On the anode side, the O^{2-} ions undergo an electrochemical reaction with hydrogen atoms contained in a supplied fuel. Electrons and water are generated. A schematic of a solid oxide fuel cell is shown in Figure 2. The solid oxide fuel cell operates at high temperatures (around 1000 C) in order to increase the diffusion rate of the O^{2-} ions across the electrolyte. Due to this high operating temperature, ceramics are the material of choice for the anode, cathode, and electrolyte. Ceramic nanomaterials are used in the layers to make them as thin as possible and to increase the diffusion paths for the O^{2-} ions.[12] Students learn about the ceramic materials, ceramic crystal structures, ionized defects, ceramic phase diagrams, and diffusion. Details of this module, including class by class learning objectives have been published previously.[11]

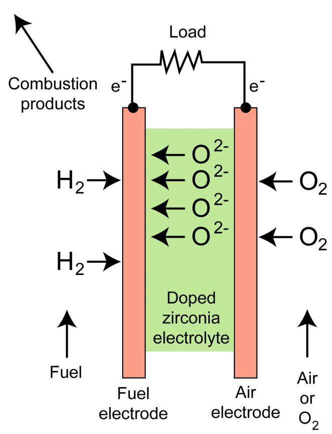

Figure 2: Schematic of a solid oxide fuel cell.

Sports Materials: Polymers and Composites Used in Skis

The high tech world has entered the sports arena with many different sports using materials engineering to give their athletes an edge over competitors. The skiing industry is no different. Composite skis have been engineered to maximize strength and reliability while minimizing weight.[13] In this module, students learn about the processing and mechanical properties of polymers and composites as they relate to skis. Specifically, the design of skis using advanced polymers such as Kevlar® is covered. The module includes the basics of polymers and polymer crystal structures, polymer synthesis, the mechanical and thermal properties of polymers, and the design and mechanical properties of polymeric composites. The specific learning objectives of this module are given in Table 3.

Table 3: Learning objectives in the PRIME sports materials module.

Week 1: Introduction to ski technology and polymer structure	Define monomer and polymer Describe the initiation and growth of a polymer chain Describe the molecular structure of polymers: linear, branched, crosslinked, and network Calculate the average molecular weight of a polymer Describe the difference between thermoplastic and thermosetting polymers Draw the monomers for polymers commonly used in skis Discuss the factors used in choosing a monomer type for skis
Week 2: Mechanical Properties of Polymers	Generate a stress/strain diagram for a polymer from experimental data Use a stress/strain diagram for polymers to determine yield point, ultimate tensile strength, and Young's modulus Determine how the degree of cross-linking influences mechanical properties Define and identify applications for thermosets, thermoplastics, and elastomers Describe elastomeric hysteresis Describe the impact strength of polymers Describe the fracture properties of polymers Analyze stress strain diagrams for polymers used in skis and determine how processing affects the mechanical properties
Week 3: Composites	Name the three main divisions of composite materials Cite the distinguishing features of each main type of composite material Name the three different types of fiber-reinforced composites Describe the distinctive mechanical characteristics of each type of fiber-reinforced composite Calculate longitudinal modulus and strength for an aligned and continuous fiber-reinforced composite Select matrix and fiber materials for composites used in skis based on strength-to-weight and cost issues

<u>Civil Infrastructures: Fiber Reinforced Plastics for Civil Infrastructure</u>

Fiber reinforced plastics (FRP) are composite materials with a polymer matrix and a glass, carbon, or aramid fiber reinforcement. Common uses for FRPs generally occur in the aerospace, automotive, and marine industries as low weight, high strength materials. The durability is a function of both the matrix and the fiber making the composites much more durable than the fibers on their own. The strength, however, is more influenced by the fibers making the composites very strong in tension. FRPs are used in civil infrastructures for reinforcement for concrete patching, cables on bridges, and complete bridges. The major advantages of FRPs over steel are that the material can be more specifically tailored to the loads for the system, a resistance to corrosion, an increase in material lifetime and durability, and a decrease in construction time and cost. Materials engineers are researching ways to improve the cost, strength-to-weight ratio, and long term reliability of FRP composites used in civil infrastructures.[14] In order to successfully understand FRP applications, students must master the fundamentals of both polymers and composites including the structure, processing, and mechanical properties of these materials. Details of this module, including class by class learning objectives have been published previously.[11]

Microelectronics Module: Emerging Devices for Non-volatile Memory

Students explore emerging devices for non-volatile memory storage in the microelectronics module. Traditional non-volatile memory including magnetic hard drives, floppy discs, and Zip discs are not used in most portable electronic devices because of their relatively large size, the size of their read/write components, and the fact that they can't be integrated well with Si electronics. FLASH overcomes these problems and is currently the standard non-volatile memory technology used in portable, electronic devices. FLASH components are based on N-MOS transistors, see Figure 3. This technology creates 1s or 0s in memory by storing (or not storing) electrons on a floating gate. This affects the turn-on voltage of the transistor, which is how the memory state is read. Ultimately, there is a scaling limit to FLASH and engineers are researching the next generation of memory technology.[15] In studying FLASH and other emerging non-volatile memory options, students learn about the electrical properties of metals and semiconductors, semiconductor doping, p-n junctions and transistors, and magnetic materials. Details of this module, including class by class learning objectives have been published previously.[11]

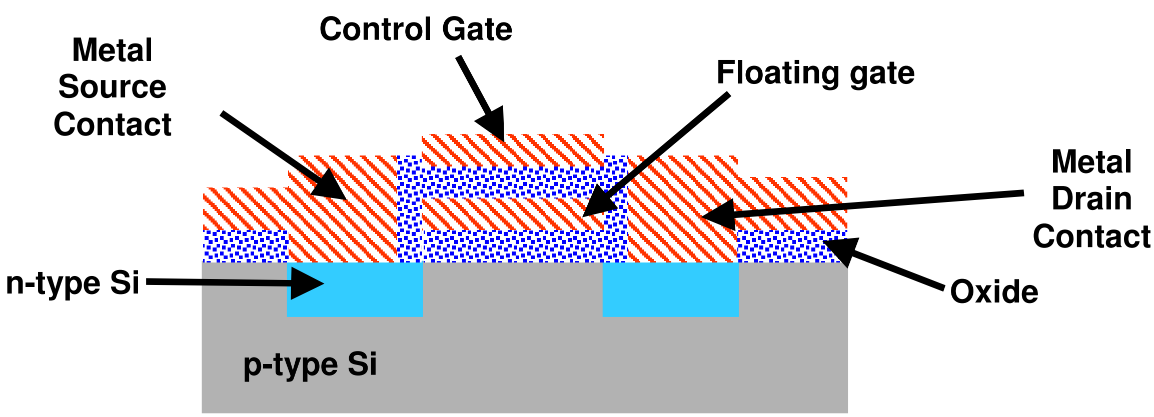

Figure 3: Cross section of a FLASH device.

Assessment

The assessment data reported here is from Prof. Gleixner's Introduction to Materials course at San Jose State University. Use of the modules by other instructors at San Jose State and other institutions is underway, but the assessment results are not completed for those courses. Prof. Gleixner has developed, utilized, and revised the modules in her course for four semesters. In Spring 2005, she utilized two modules and taught half the course in a traditional manner. During Fall 2005, Spring 2006, and Spring 2007 she taught the whole course in the module format, using 3-4 modules per semester. All of these courses were large (65-80 students) with a mix of engineering majors but predominantly mechanical and civil engineering undergraduate students.

The general response from students is that they enjoy the modules and they feel they are an effective way of learning the material. Figure 4 shows the results from an anonymous survey in Spring 2005 with 64 respondents. Most of the students (39%) enjoyed the Introduction to Materials course a lot or somewhat more than their other engineering courses. The majority of students (69%) self-reported learning a lot or somewhat more in the Introduction to Materials course relative to their other engineering courses. Note that this survey is the self-reported opinions of the students and does not control for separating out the instructor effectiveness and the general content of the course from the module format.

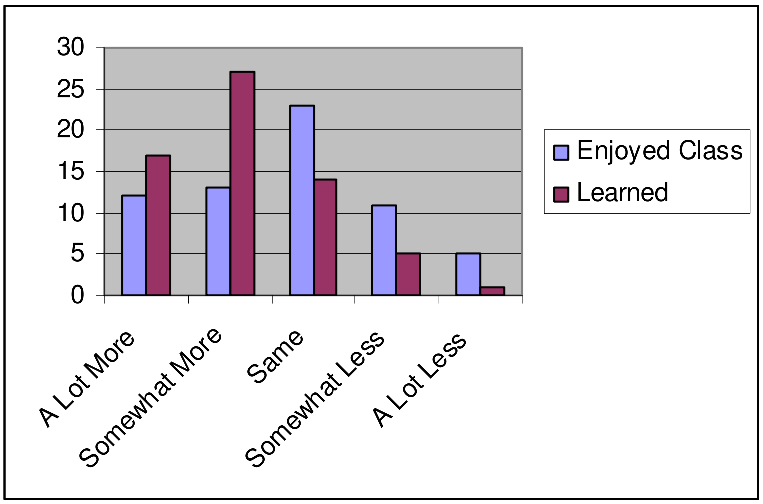

Figure 4: Students self-reported opinions on whether they enjoyed their introduction to materials course and how much they learned relative to their other engineering courses. This was from a Spring 2005 anonymous survey with 64 respondents.

Table 4 details some of the common positive and negative responses from students on anonymous, written surveys. These were comments students wrote in on the university wide survey form on teacher effectiveness. The sections from which these written comments were garnered asked the students to comment on the "strengths of the instructor's teaching", "weakness for this instructor's teaching", and "any other comments". In general, there were significantly more positive than negative comments. Both are included in the table to highlight some students' perceptions of the pros and cons of the module format. The written feedback on student evaluations indicates that, in general, students value the main aspects of the modules including the use of the technologies, organized PowerPoint slides, active in class exercises for each class, and projects. Students appreciated the fact that the fundamental material is repeated in the modules. Negative comments indicate some students are bothered by not following the textbook order and having to learn extra material outside of the text. In Fall 2005, a number of students responded that the instructor went too fast in class. This has been rectified by minimizing the use of the PowerPoint slides and increasing the board writing. That semester, four modules were done, each one involving a project. This was an overwhelming amount of work for both the students and faculty. The instructor has switched to only having two projects per semester, that is not having an outside project for every module.

Table 4: Samples of typical comments related to the PRIME modules that were expressed by students on the university wide anonymous survey for teacher effectiveness for Spring 2005, Fall 2005, and Spring 2006.

Positive student comments related to the modules
"The material is presented in a manner that captivates the class. A lot of references to its application in industry." "I greatly enjoyed the class and am switching majors. Thank you." "Very good notes", "Good PowerPoint presentations" "Always has a group problem solving activity for each class", "Class is interactive for students keeping everyone involved" "Slides summarize important points relevant to class" "A lot of useful material online", "Great website" "Interesting projects", "Projects were directly related to our future careers" "Good repetition of key facts for better retention"
Negative student comments related to the modules
"A lot of reading" "Projects require too much work for a 3 unit course" "Required us to learn extra information we won't need in our majors" "Jumping around the chapters confused me more than the traditionally taught engineering courses" "Covers the material too fast" *(from Fall 2005, see comments in text above) "Too many projects" *(from Fall 2005, see comments in text above)

Figure 4 reports students self-reported opinion of how much they learned with the PRIME modules relative to their other engineering courses. The Materials Concept Inventory Quiz (MCI) was administered to assess the learning from a quantitative standpoint. The MCI is a multiple choice test designed to gauge student understanding of fundamental materials concepts.[16] The test was administered anonymously to San Jose State University students taking the Introduction to Materials course in Fall 2005 and Spring 2006. Each semester there was a traditional format section of the course and a PRIME Modules format of the course. The PRIME Modules format course both semesters (Fall 05 and Spring 06) were taught by the same instructor. The other two sections of the traditional format course were taught by two different instructors. The test was administered at the beginning and end of the semester to all sections. The results are given in Table 5. The scores are out of a possible 30. The relatively low final scores reflect that the questions on the MCI do not directly relate to the material taught in the course. The low exit scores from these introduction to materials courses are similar to those reported in the literature.[17] Note, in the Fall 2005 pre-test, it was not recorded which lecture section the student was in. However, comparing to the pre-test data for Spring 2006, there was essentially no variation in the lecture sections at the start. The variation in results seen from the same instructor semester to semester (Instructor A with the PRIME modules) and between different instructors is comparable. This data indicates that, within the scope of concepts covered by the MCI, the PRIME module format successfully teaches the same level of fundamental concepts as a traditional format.

Table 5: Results of pre-tests and post-tests for the Materials Concept Inventory Quiz. The quiz was given anonymously to Fall 2005 and Spring 2006 sections of Introduction to Materials courses using the PRIME modules and a traditional format. Scores are out of a possible 30.

Course	Pre-Test			Post-Test		
	#	Average	St Dev	#	Average	St Dev
Overall Fall 2005	70	9.65	3.44	80	11.85	3.98
PRIME Modules, Fa 05 Instructor A				44	12.20	4.16
Traditional Format, Fa 05 Instructor B				36	11.78	4.31
Overall Spring 2006	129	9.55	3.27	121	11.95	3.78
PRIME Modules, Sp 06 Instructor A	69	9.54	3.18	61	11.69	3.39
Traditional Format, Sp 06 Instructor C	60	9.56	3.40	50	12.29	3.37

Feedback from the faculty is that the modules are a lot of fun to teach and a very effective way of organizing the course. In a traditional mode, the faculty felt a disjointed skip in the flow of the course after each chapter in the text. Students were not relating the material together and were not seeing the relevance of the topics to engineering. With the modules, the curriculum flows well from topic to topic under the overarching theme of the technology. Results of student feedback, Table 4, show that students in general value learning about the technology and seeing how the fundamental concepts are applied.

Difficult concepts such as crystallography and phase diagrams are revisited later in the semester. The repetition of material in the modules not only helps students see the role these topics play in different technologies, it also helps facilitate a deeper understanding of the material. The faculty feels this has been highly effective at soliciting student engagement and questions. The second time they see the material, the students seem more able to analyze the problems at a higher level. The repetition of this material along with time during lecture spent talking about the technologies does reduce the amount of topics that can be covered in the class. The module format has a trade-off between learning less topics at a deeper level versus covering a broader range of topics.

One of the primary goals when developing the modules was that they would increase students' interest in the curriculum and thus increase the time and effort they devoted to learning.[2-5] The faculty has found that, while the modules seem to increase student enthusiasm in the course, this has not translated to an increase in the students' motivation to learn. In order for the module format to be completely successful, students should come to the class period ready to actively engage. The goal of the class is to take the students' understanding of the material to a higher level by applying the concepts to the technology. While students in general seem to enjoy the class (Figure 4), the faculty has not noticed an increased preparedness for class. For example, ideally the students should come to class having read the assigned textbook reading and reviewed the reading review notes and learning objectives provided for that section. This would allow less time to be spent reviewing the basic concepts and the students would be able to more quickly engage in the active learning exercises. However, the average student is not reading before class and is not prepared to start in on active calculations or higher level discussions of applying the concepts to the technology. More research needs to be done to understand why students are not fully preparing for class and what can be done to motivate them. These assessments of student motivation detailed above are the impression of the faculty. The impact of the modules on student's motivation to learn is currently (Spring 2007) being assessed with the Instructional Materials Motivation Survey (IMMS). This is a 36 item instrument in which students are asked to rate various statements regarding the instruction they have received using a Likert-type response set.[18]

Summary

Project based modules were developed for use in an Introduction to Materials Engineering course. The modules teach the fundamental concepts of materials science within the context of modern engineering applications. The main goals in integrating the fundamental concepts with advanced technologies is to help students see the connection between what they are learning and real world engineering issues and to motivate them to learn on their own.

Five lecture modules have been developed. Each is designed to take 3-5 weeks of class time. The technologies focused on the in the modules are biomaterials used in self-expanding stents, ceramic nanomaterials for solid oxide fuel cells, non-volatile memory options for portable electronic devices, polymers and composites in skis, and fiber reinforced plastics used in civil infrastructures. Throughout the course of each module, teams work on open-ended projects that help them relate the fundamentals to the technology. The projects are used to increase student ownership and motivation in learning.

In addition to the projects, the module development includes background resources for faculty and students on the technology. This allows the modules to be taught by faculty with little or no experience in the technology area. Each class period of the module has learning objectives, a reading assignment with reading review notes, instructor notes and overheads, active in-class exercises, and homework problems related to the technologies.

39% of the students surveyed enjoyed the module format more than their other engineering courses. 69% students self-report learning more than in their other engineering courses. Within the scope of the concepts tested on the Materials Concept Inventory Quiz, students in the module format version of the course learn the fundamental principles at the same level as students in a traditional course. Faculty perception is that the modules are a fun and effective way of organizing the material. Curriculum flows well together under the theme of the technologies. The faculty's impression is that the modules have increased student enthusiasm for the course but have not greatly improved students' self motivation to learn.

Acknowledgements

The curriculum development work reported in this paper is supported by an NSF, CCLI-EMD project, "Development of Project-Based Introductory to Materials Engineering Modules" (DUE # #0341633).

Bibliography

1. Private Communication, Jonathan Plant, Senior Sponsoring Editor: Mechanical, Materials & Aerospace Engineering, Mc-Graw Hill.
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).
4. A. Cabral, R. Viau, and D. Bedard, "Situated Learning and Motivation Strategies to Improve Cognitive Learning in CE", *ASEE Annual Conf. Proc.*, (1997).
5. C.L. Dym, A.M. Agogino, O. Eris, D.D. Frey, L.J. Leifer, "Engineering Design Thinking, Teaching, and Learning",*J. of Engineering Education*, **94(1)**, p. 103 (2005).
6. K. C. Chen, B. London, L. Vanasupa, T.T Orling, and L. Christensen, "Travelogue from the Materials World: A First Week Laboratory Activity", *ASEE Annual Conf. Proc.*, **3664** (2004).
7. W. D. Callister, Fundamentals of Materials Science and Engineering: 6^{th} Edition, John Wiley and Sons, (2001).
8. PRIME website: http://www.engr.sjsu.edu/sgleixner/PRIME/
9. M. Alley, M. Schreiber, and J. Muffo, "Pilot Testing of a New Design for Presentation Slides to Teach Science and Engineering," *35th ASEE/IEEE Frontiers in Education Conf.,* T1A-1 (2005).
10. D. Stoeckel, "Nitinol Medical Devices and Implants", *Min. Invas. Ther. & Allied Technol.*, **9**, p. 81 (2000).
11. S. Gleixner, O. Graeve, E. Douglas, "Project Based Introductory to Materials Engineering Modules on Biomaterials, Solid Oxide Fuel Cells, Non-volatile Memory, and Fiber Reinforced Plastics", *ASEE Annual Conf. Proc.*, (2006).
12. S.P.S. Badwal and K. Foger, "Solid Oxide Electrolyte Fuel Cell Review," *Ceramics International*, **22** p. 257 (1996).
13. H.C. Boehm, "Influence of Composite Materials on Alpine Ski Design", *SAMPE Journal,* **15(5)**, p. 14-20 (1979).
14. J.S. O'Connor, J.M. Hooks, "A Summary of Six Years Experience using FRP Composites for Bridge Decks", *Intl. SAMPE Technical Conf.,* p. 2903 (2004).
15. K. Kim and G-H. Koh, "Future Memory Technologies Including Emerging New Memories", *IEEE Proc. 24^{th} INTL. Conf. on Microelectronics,* **1**, p. 377 (2004).
16. S. Krause, J.L. Decker, J.L. Niska, T.L. Alford, and R. Griffin, "Identifying Student Misconceptions in Introductory Materials Engineering Courses", *ASEE Annual Conf. Proc.*, p. 732 (2003).
17. W. Jordan, H. Cardenas, C. B. O'Neal, "Using a materials concept inventory to assess an introductory materials class: Potential and problems", *ASEE Annual Conf. Proc.*, (2005).
18. Keller, J.M., "Development and Use of the ARCS Model of Motivational Design," *Journal of Instructional Development*, **10(3)**, p. 2 (1987).