AC 2010-172: INSTRUCTION OF PROFESSIONAL SKILLS TO MATERIAL SCIENCE AND ENGINEERING STUDENTS USING A MULTI-YEAR MODULE APPROACH

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Instruction of Professional Skills to Material Science and Engineering Students using a Multi-Year Module Approach

Abstract

A course has been developed at Carnegie Mellon University in the Department of Materials Science and Engineering that is specifically focused on the continual development of professional traits in our students. This course is delivered in three modules taught over three fall semesters allowing the students to absorb the skills without the time constraints of a typical technical class. Success of this course is predicated on keeping topics relevant to the students and the changing workplace. The current content is presented for the three modules. Delivery of such a course requires the ability of the faculty teaching the course to build upon the topics discussed in prior modules. This continuity is further benefited by a constant renewal of topics and a yearly evaluation of the student body in terms of interest, maturity, dedication, and learning skills.

Introduction

As the engineering student population has become more diverse and as the interests of the students have evolved, today's graduating engineering students often seek employment in professional environments that are non-traditional and present more challenging professional settings. In the Department of Material Science and Engineering (MSE) at Carnegie Mellon, when implementing a Professional Topics class for our students, we set out with two goals; the first was to teach professional skills required of materials engineers with the wider workplace in mind; the second, to illustrate the personal challenges young graduates will face in their teams, their companies, their industry, and the global workplace.

Teaching professional skills in a technical curriculum can be challenging. Scheduling issues always present as a problem, but also, often engineering faculty do not have the interest or the practical experience to address these topics. As a result, varying approaches have been taken; total outsourcing to the humanities department, inclusion of professional topics within a technical course, or instruction as a dedicated subject such as Engineering Ethics in the engineering school. Each of these approaches focuses on providing an intensive one-time immersion of the student into the topics required for personal growth and professional skill development. Our approach breaks from this structure and addresses these topics with a course that meets weekly for one hour during the fall semester of the sophomore, junior and senior year. With mandatory attendance of all students, sophomores through seniors, the content of the course can be rotated over the span of three year period so that each student will be exposed to the entire content. The course is segmented into three modules,

1) Skills for the Work Environs
2) Teams and Project Management
3) Ethics

By having the students attend each of these modules, the students are exposed to approximately 45 hours of instruction in professional behavioral issues during their degree.

One of the specific goals when developing the extended course over the entire three years was to place significance on the comprehension of professional behavior. There is no question that the entire content could be addressed in a one semester course, however, it is felt that such approach only serves to focus attention on this topic for the duration of the semester. It would be more desirable to have professional skills taught in a manner that would allow each skill to built upon, practiced and reinforced as behaviors as opposed to being "lecture" taught. The extension of the course topic over a three year duration provides two key learning objectives, first, the ongoing nature is a reminder to the student that these topics are lifelong learning topics, and second it allows the students to observe, develop, and test their profession skill set as the they mature.

This latter point is significant. Our approach of including all three years of students into the same class provides an unique opportunity where students can experience different views and interpretations that are a reflection of their maturity. Our desire is to try to exploit the fact that sophomores look for some leadership and guidance from the more "experienced" seniors, and that seniors can look back at their personal growth in the few years spent in our program. These small maturity differences are effective at reinforcing the importance of professional behavior.

The Professional Topics course is a required course in our Materials Science and Engineering core curriculum, and although the course is not specifically designed to teach fundamentals of materials science, wherever possible, we attempt to expose actual materials engineering related problems as examples and discussion. In developing the course content, the author has relied on personal experiences in workplace, on training programs during his years in technology business with several corporations, and the wealth of information now available on the subject. Assignments, when used, (for example in project management or business planning) employ case studies or typical assignments a material scientist or engineer may encounter during his/her employment. With this content, we feel we have assembled a modern skills building based seminar series having primary emphasis on the ABET Outcomes F (an understanding of professional and ethical responsibility), H (the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context) and I (a recognition of the need for, and an ability to engage in life-long learning). A secondary emphasis is placed on an ability to communicate effectively and on knowledge of contemporary issues in a material science career (Outcomes C and J). The classes themselves are a mix of lecture and discussions updated to include specific topics of relevance for young professionals going into either science, engineering, or business careers. Many of the lessons are reviewed and built upon in other courses, in labs, and the capstone project course.

Module on Skills for the Work Environs

This section of the course encompasses lectures that address a range of topics relating to professional development, creativity, innovation, and non-technical enrichment. The learning objectives for this module are to have students become aware of work environment expectations for material scientists, to have the students recognize their personal skill set, and have them

develop awareness of the employment issues that will help them transition from student to their professional careers.

The course begins by exposing the students to global business strategies and the demands of engineering positions in a global business environment. Specifically in these discussions, the global workplace is discussed for academic researchers, engineers, and businesses. The desired outcome is to have the student fully aware of the competition he/she faces in today's employment market and the opportunities that exist for a participant in the global work environs.

The second portion of this module investigates the fundamental social interactions and psychology that underlie typical work activities. To begin, the students are introduced to general personality trait measures that help them identify their interests, likes, and dislikes. Students are then encouraged to visit our career center to complete an accurate Meyers - Briggs Inventory. Getting this basic understanding of how they view the world, the student can being to reconcile how they fit into the workplace in terms of team structure and performance, leadership positions, as communicators, as engineers, scientists, or as businessmen/businesswomen. In our particular student population, this self-examination has been beneficial as many of our students are oriented more toward science and less oriented toward traditional engineering and industrial workplace settings. By understanding even the rudimentary basics of their personal traits, these students are often able to recognize their complimentary strengths and interests that lie outside or on the fringes of the materials engineering discipline. Recognition of these strengths is important and can often help a student subtly shift their education to accommodate their interests. The ability of students to find areas of comfort helps to ensure lower attrition rates, a healthy student diversity, and a broad based engineering education with many students completing minors, supplementing their degree with courses from other disciplines (School of Design, Business School, School of Music), obtaining dual degrees in Materials Science and Engineering and Biomedical Engineering and Materials Science and Engineering and Public Policy or completing their engineering degree as a precursor to entering another professional school such as medical, dentistry or law.

Building on the personal development, the course continues by addressing leadership skills, communication skills, innovation, and creativity. These topics are introduced through discussion about the business of engineering, and the expected value that engineers are expected to contribute to a business venture. By covering these topics, students learn to appreciate the creative and innovative nature of engineering and get a better understanding of the talents and skills that are being sought by corporation for the engineering workplace. They also develop (often for their first time) a vision of what their strengths are and how and where they can be applied after graduation. Past history within our department has shown that approximately 50% of graduates enter engineering related occupations while the remainder pursue more science based occupations (including graduate school). To meet the expectation of both workplaces is a matter finding commonalities. A good deal of the focus in this portion of the module is on having the student understand the demands of today's work place, such as travel, multi-role employment, professional and personal life balance, and the need for lifelong learning. One effective teaching method employed for this is to have a guest speaker addressing specific employment demands experienced during transition to the workplace. It seems to be particularly beneficial if this is a recent graduate to whom the students can relate.

Our outcome expectation for students completing this year of professional development is that they are able to define their own personal goals as they move along their career path and that they are able to begin to self-evaluate themselves in the role engineers or scientists and to do so with some understanding of the global business strategies in the current work environment.

Module on Teams and Project Management

This module of the course aims to illustrate the issues relating to the practice of using teams in engineering and scientific business environments. The students learning goals are to develop an understanding of the basic psychology of team formation and performance. This topic builds upon the first module by further extending the students knowledge of interactions between individuals, but now as they relate to a team environment.

With the widespread use of teams in the engineering workplace, we expect that our students will eventually find themselves being part of a team, either in engineering, research, or management. To focus the learning on the technology work environs, selections from Kidder, The Soul of a New Machine are used as study materials [(1)]. Using these readings, the students are to comment on the interactions that develop as a team is assembled and to reflect on their past experiences in teams. This reflection has proven interesting as students seem to prefer discussion of non-performing teams and at times related to lab or work groups that they have experienced during their recent education.

Through readings, lectures and discussion, the fundamental stages of team construction and performance are explored and students learn the complete life cycle of a team, the benefits of team formation, as well as the difficulties that can impede team performance. This often provides insight to many of the non-performance issues raised by students in during their earlier reflection on teams in general. As part of the discussion on non-performance team issues, a video illustrating Groupthink [(2)] using the Challenger is used to help illustrate the catastrophic outcomes of poorly performing teams and the breakdown of communication between teams having differing agendas. We want to have the students understand that engineering teams are dynamic entities that are a function of the personalities of the team members and team leaders, and that teams are driven by both technical, and business goals. Since the students have already explored their personality traits in the first module of the course, they begin to see how they fit into team social structures as leaders, communicators, or regular team members.

Following the analysis of team sociology and communication issues, the module on team dynamics concludes by addressing team conflicts and resolution techniques. Students are taught to recognize the common origins of team conflict within organizations, and how to resolve issues while recognizing the importance and views of typical stakeholders. We hope to have the students be able to recognize potential conflicts and be in position to preemptively address these using interpersonal skills and/or third party options for resolution.

The ground work on teams and team issues, serves as a base on which we introduce the students to project management skills. The expansive scope of project management is far too broad to be

fully covered in this portion of the module. Our goal for the student in this section of the module is to be able to recognize technical and business socio-cultural components that constitute a project. The emphasis is placed on looking at engineering or research team projects from the perspective of management. By choosing this perspective, the student sees how the science, engineering, financial, and business strategies are all intertwined within the project and how management expects teams of a multi-discipline nature to perform.

Within the framework of the materials business, the students are shown how to employ work breakdown structures, tasks definition, budget estimation and schedules for a simple project. Advantages and disadvantages of different scheduling techniques are shown for various types of projects , from small lab projects in science based research, up through large construction and installation projects. The students are assigned a problem that requires them to show that they can develop, prepare, and use the project management techniques taught in this section of the course for a small scale materials engineering project.

Once the students have demonstrated that they understand what is to be managed during a project, we begin to explore the use of projects to achieve a determined business goal. Different corporate organizations, behavior, staffing, information flow, and communication issues that influence project goals are discussed. Project goals are then presented from the differing viewpoints of supplier project management and client project management. The differences of these two roles is often overlooked in project management education, however there are distinctly differing goals for each organization (supplier and customer). To emphasize the difference, attempts are made to bring in guest speakers that can give practical experiences relating to both sides of this project management fence.

To complete the study of project management, project tracking and control mechanisms are discussed. Examples of project documentation, calculations of earned value engineering, scope and time creep are illustrated so the student can become aware of issues that threaten project management. Finally the topic concludes with discussion on risk management and project control options.

Our outcome expectation for students from this module is that they are able to function as leaders or members of successful teams in the engineering workplace. We expect our students to have a basic ability to recognize and be aware of the influences that human personalities, social norms, and business and management demands have on team performance and project expectations. Students are expected to be able to use rudimentary project skills and to be able to build upon this knowledge for more sophisticated projects.

Module on Ethics

The specific goal of the ethics module is to have the student understand the need for developing an ethical sense, rather than just be a platform for exposing them to ethical theories. The module begins with a series of readings and discussions used to draw out the importance of correct decision making as engineers. As a learning tool, students use the the Carter Racing series which parallels the decision making in the Challenger tragedy. Students learn quickly that in some

engineering situations, decisions are made with incomplete or sketchy data.

Having discovered that there is a need for some guidelines for decision making, the basic philosophies of Utilitarian, Kantian, and Rights based ethical decision making are presented in brief. Example cases are used to illustrate the differences in each of these philosophies but the module does not dwell on the need for students to understand the detailed ethical theory involved. The desired outcome is to have the student recognize that differing approaches and interpretations exist for decision making, and that they themselves need to develop a standard model that they can apply.

To begin students questioning their ethical boundaries, we begin with a discussion of cyber ethics as it applies for students, then expand this to the work environment envisioned by our students. The work environment is explored in more detail by continuing discussions into the ethics of scientists. For this discussion, the NAP publication “On Being a Scientist” is used to point out and highlight ethical issues that may present themselves in a scientific career[(3)]. We continue on into engineering ethics through discussion of the implied social contract and then review of ethical guidelines established by the professional societies.

Up to this point in the course, the ethics for decision making has been dominated by the western model. To prepare our students for the global workplace, cultural differences that influence engineering and business in Asia, Europe, South America, and even our close trading partners, Canada, and Mexico are discussed. With our usual widely diverse student population, there are often excellent personal inputs presented by students to help clarify how a particular culture may interpret an ethical issue. From these discussions, students see the international nature of engineering and get a good understanding of how culture can influence the societal expectations of engineers.

As the module continues, the international nature of engineering is expanded upon in two ways, the first is by introducing the topic of environmental responsibility. Today's students are very aware that as engineers of tomorrow, they must become the environmental stewards. Ethical issues dealing with engineering choices regarding process selection, pollution, plant siting and operation, and employment conditions are all topics the students find engaging. We conclude this by reviewing US law applicable to foreign facility management and discuss the implications of these laws on decision making by engineers based in US corporations. The second expansion opens up the internationally biased topic of business ethics. This is an important topic because of many of our graduates will end up in management positions. To be sure relevant topics are being presented to our students, resources are drawn from the Tepper School of Business at Carnegie Mellon[(4)]. This work essentially parallels the international aspects of engineering, looking instead at the ethical issues relating to environmental and legal business practices in international settings.

Following the introduction to business ethics, the overlapping interests between business and technology are looked at through intellectual property ownership. Here the IP issues of individual versus corporate ownership and the consequences of the control decisions are illustrated to help students understand their rights for developing, controlling, and using controlled information. This topic is approached for both the scientist and or graduate student

working in open environments and for engineers working in a corporate entity.

Lastly, the ethic module wraps up by exploring possible consequences of ethical decisions. Case studies are discussed with students to illuminate the severity of possible consequences to whistle blowing. Guidelines to managing reporting, the need for professionalism, and possible work around solutions for problems are discussed.

At the conclusion of this module, students must complete an open note test to ensure students have knowledge of the ethical issues of importance to scientist and engineers. Our desired outcome is to have provided the basis for the student to begin to self-analyze their behavior in an ethical sense. Our students should be able to recognize western ethical ideals, know that there are cultural differences, yet be able to conduct themselves within this framework whether in science, engineering, or business.

Summary

It is always difficult to provide a definitive measure of the outcomes of courses designed for personal growth as students are in a continual maturity process throughout their years of study. To have our students be successful, we opted to design a course that takes advantage of this maturing process and once a year addresses and reinforces the importance of professional skills. The subdivision into three modules taught over three fall semesters seems to provide a workable delivery. This avoids the students from being exposed to an intense course over a short time period where the students goals foremost focus is to attain a desirable grade.

Feedback from our industrial constituents and from the advisory board members are extremely positive regarding this program. Some industry members have commented that it contains many of the same topics their companies address during their own training programs for managers after graduation. Happily, this was our intent. Direct student feedback has not been formally sought but informal discussion with past graduates is used to help update and refresh the content. This course replaced a open seminar course and following the first year of implementation, no students complaints have been reported from our student advisory council (undergraduate student council for course complaint feedback) other than an objection to additional work required for the project management module.

References

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(2) Groupthink, CRM Learning LP., http://www.crmlearning.com
(3) The National Academies Press, http://www.nap.edu/books/0309051967/html/index.html
(4) John Hooker, Tepper School of Business, Carnegie Mellon University, personal communications