Integrating Professional Ethics into Technical Courses in Materials Science

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During the Fall semester, 1997, I incorporated ethics into three classes, MSM 454 (a senior-level Materials Science class), EGR 291 (an "introduction to engineering and university life" course, open to all first-semester engineering freshmen), and MSM 885 (a graduate-level Materials Science seminar). Including ethics in MSM 454 was the focus of a follow-up to an NSF-sponsored "Ethics Across the Curriculum" Workshop I attended in July, 1997, at Center for the Study of Ethics in the Professions (CSEP), Illinois Institute of Technology. The "Ethics Across the Curriculum" workshop was a continuation of a personal interest in teaching ethics (I also attended the NSF "Teaching Research Ethics" Workshop at the Poynter Center, Indiana University during the summer of 1996).

This paper describes the handouts, homework questions, examination questions, and in-class discussions included in the ethics component of the two Materials Science courses, MSM 454 and MSM 855. (I'll focus on incorporating ethics into Materials Science courses, so I will not discuss the general freshman engineering course EGR 291, although teaching EGR 291 was certainly an interesting experience.) As part of this paper, I will comment on what went well, what did not go as well, what I'd do differently next time, and what the students' reactions to the course were.

As part of an initial introduction to ethical issues, the MSM 454 class was given copies of the code of ethics for NSPE and for the American Ceramic Society (I'm a long-time member of the American Ceramic Society.) One important aspect of giving the Engineering ethics codes to the class was to introduce the fact that engineering codes exist and that a number of engineering ethics codes have striking similarities. For example, the ABET (Accreditation Board for Engineering and Technology), the NSPE Code, and the ACeRS Code all feature the phrase "Engineers shall hold paramount the safety, health, and welfare of the public".

In MSM 454, the third homework assignment (Table 1) was the first graded assignment dealing with ethics. The class was asked to cite specific, appropriate sections of the NSPE Code of Ethics in response to various ethical problems. The first three questions of the homework set were:

1. In the six months since you've had your job at Fire, Inc., you have been in charge of firing high alumina (99.99% pure Al_2O_3) components at 1650° C for one hour, using high alumina setters. Your boss Bill asks you to fire new silica (SiO_2) components. To your question of "What firing conditions do you want me to use?", Bill answers, "Oh, the same as you have been using for the high alumina stuff."
a.) Using the <u>$Si0_2$ - Al_20_3 phase diagram</u> on page 279 of the text, what is a "maximum" safe temperature in this case?

b.) Refer to the NSPE Code of Ethics (handed out earlier in class). Discuss the ethical problems/concerns here (if there are none, explain your reasoning).

2. Redo number 1, with the changes:
(a) Mg0 components instead of $Si0_2$ (refer to Phase Diagrams for Ceramists, included in the additional reading/references list in the library).
(b) Instead of your boss Bill, it's your friend Walt (who does not work for Fire, Inc.) who asks you to fire the Mg0 as a "freebie". He asks you not to mention it to your boss.

3. Redo 2(b), but now Walt offers to pay you $200 for each set of 100 (fired) components you deliver to him. Again, Walt asks you not to mention it to your boss.

Except for two or three students, the class took the ethics component of the homework quite seriously, citing appropriate sections of the NSPE Code. For question 1(b), several students cited the "Professional Obligations" section of the NSPE Code, namely III.1.b, which states "Engineers shall advise their clients or employers when they believe a project will not be successful." For problem 1, there is a binary eutectic between alumina and silica at $1587^{O}C$ that could lead to melting if silica components are heated at $1650^{O}C$ on pure alumina setters. In a class session dealing with binary phase diagrams, it was discussed that such melting can lead to serious damage to the furnace. Using their technical knowledge to recognize the danger of extensive (and expensive) equipment damage, the students also acknowledged their ethical responsibility to tell their employer that the project (the firing of the silica components at $1650^{O}C$ on the alumina setters) would not work.

Table 1. MSM 454: Schedule of class activities involving ethics

Week	Classroom Activities
9	Ethics codes for National Society of Processional Engineers (NSPE) and American Ceramic Society (ACeRS) given to class, discussed professional ethics codes for engineers.
11	Homework problems dealing with ethical issues.
12	Discussion of ethical problems from the homework in reference to Seven Step Guide[1]
13	Examination problem involving ethical question, cited NSPE Code.
14	Further discussion of Seven Step Guide[1], discussion of handbook versus problem-solving schema for both technical and ethical problems.
16	Final examination included a problem dealing with professional ethics. Seven Step Guide[1] given to class to assist them in responding to ethics question.

For question 3, many students cited Section II.4.c. of the NSPE Code: "Engineers shall not accept compensation...from outside agents in connection with work for which they are responsible" and Section III.6.c: "Engineers shall not, without consent, use equipment, supplies, laboratory or office facilities of an employer to carry on outside private practice". Thus the class was able to use the NSPE to address very specific ethical issues.

The fourth question of the homework set involved materials science aspects ternary phase diagrams, while the fifth homework problem addressed the situation in which "there are no binary (or ternary) phase diagrams among the thousands of diagrams in Phase Diagrams for Ceramists" (or other, similar references) "that include the material 'A' and alumina in equilibrium" and to discuss "both (a) the technical approach to the problem and (b) ethical questions that might arise in this situation".

During lecture, I made an analogy between (1) the technical aspects of the course and (2) the ethical concepts. For the "technical" part of the analogy, we discussed the multi-volume **Phase Diagrams for Ceramists**[2], which are handbooks that encapsulate a great deal of experimental information concerning equilibrium phase diagrams. Such handbooks are of great practical utility, but no single compendium incorporates every possible combination of materials systems found in practice. One may need to "transcend" the handbook and to apply fundamental scientific principles to everyday phase equilibria questions such as "If I heat these two materials together during this particular test, will I melt the materials rather than, say, testing their high temperature mechanical strength?". This concept underlies much of engineering and science. Students must efficiently and correctly apply handbook information, but they also need problem solving skills to cope with situations not covered by the handbook, or instances when no handbook is available.

The NSPE Code of Ethics is in sense a "handbook" that evolved as a practical response to a range of ethical problems experienced by practitioners in a particular professional society. However, to engage a full variety of ethical problems, one must have a general method to solve ethical problems, based in fundamental ethical principles, so that one may transcend the "handbook" code of ethics. In the technical world, handbook "experience" and scientific problem solving techniques (guided by scientific principles) can work together synergetically. Likewise in the ethical world, handbook experience (ethical codes) and ethical problem solving schema (guided by ethical principles) can reinforce one another. The class seemed to appreciate this analogy.

Following the ethics codes discussions, Davis' Seven Step Guide to Ethical Decision Making[1], and the ethical-issue homework (Table 1), a question was included on the third examination that treated ethical issues involved in adding SiC whiskers to a ceramic component. The health hazards of SiC whiskers had been discussed earlier in class, namely that the government rates the health hazards of SiC whiskers on a par with asbestos. Nevertheless, on the exam, only two students mentioned the health and safety aspects (and hence also the ethical aspects) of working with SiC whiskers. The rest of the class answered the question in terms of high-temperature melting due to possible eutectic reactions at high temperatures, ignoring the health hazards involved. The attention to the phase equilibria issues at the expense of safety/ethical issues likely stemmed from the students' anticipation of an exam question that paralleled their earlier homework assignment. Thus, the answers likely were more a matter of "testmanship" on the part of the students, rather than an insensitivity to ethical issues.

The difficulties with Exam 3 prompted me to select an ethics problem for the Final Exam that focused on health and safety issues. Also, prior to the final, I announced to the class that I would give them a copy of Michael Davis' Seven Step Guide[1] to use during the exam. On the final exam, the class did address the potential ethical problems (and the related potential health problems) of using silane in the workplace. (Silane is an extremely toxic gas that can be used to produce some ceramic materials). Although I did not require the class to use the Davis' Seven Step Guide to analyze the final examination problem, several of the students did use it very effectively to answer the exam question. I was so impressed by some of the students' answers that in the future I'll include an in-class exercise that uses the Seven Step Guide to analyze the silane problem, since the Guide's concepts of stating the problem, developing alternatives, etc. are well suited to the silane question. Such a "guided" practice in ethical reasoning and problem solving should augment the other in-class discussion of ethical issues. Also, such an exercise will allow students to hear themselves and their classmates work through an ethical problem, which is an opportunity not afforded by exam questions. I am interested to see if such exercises correlate well with the students' subsequent performance on exam and homework questions dealing with professional ethics.

In contrast to the undergraduate (MSM 454) class which dealt broadly with professional ethics, in the MSM 885 (graduate seminar) class, I sought to emphasize "research ethics" and the connection of research ethics to the role of the graduate student. Initially (Table 2), I met with the MSM 885 class for about 20 minutes to explain the content and goals of the "ethics addendum" to their course. The stated goal was to introduce the class to "problem solving" approaches in professional ethics. The case study technique, which was to be used in two separate class sessions, was outlined very briefly. Then, as a motivation for the study of professional and research ethics, I discussed the case of the Bay Area Rapid Transit (BART) engineers who protested a potentially unsafe computer software in terms of the IEEE Code of Ethics[3], were fired, and then reinstated with the aid of IEEE. However, I emphasized to the seminar class that one can not guarantee (or perhaps even expect) such a positive outcome in situations involving a clash between ethical principles and cooperate plans.

Table 2. MSM 885: Schedule of class activities involving ethics

Week	Classroom Activities
5	Brief (20 minute) discussion of goals for "ethics addendum" and case study method to be used in upcoming classes.
8	The Jessica Banks Case Study[4] discussed in class
12	The Charlie West Case Study[4] discussed in class
13	Data Management discussed[5]

On the first of the two class meetings devoted to ethics case studies, we discussed the "Jessica Banks" case[4] that concerns a freshly-graduated Ph.D. who wants to take to her new university job the laboratory notes she generated during her Ph.D. studies. The argument that arises between Jessica and her former advisor regarding the removal of the laboratory notes forms the basis for the ethics discussion. The case study discussion was initiated by quickly reading aloud the case study,

then using the questions provided at the end of the case study to provoke the first comments from the class. Fortunately, the class involvement allowed the discussion soon to shift from the questions provided with the case study to a more "free-form" discussion. I recorded the important points in the discussion on the board, while adding questions and comments from time to time. I intentionally broadened the discussion from its natural focus on Jessica, her major professor, and the act of taking (or not taking) the lab notes to a discussion of the other people and institutions potentially affected by Jessica's decision as well as potential alternative courses of action. After this first class meeting, I spoke to three of the students, each of whom said that they enjoyed the case study discussions. One student confided that he thought the discussion of ethics would be "crushingly" boring, but that he was pleasantly surprised. Another student suggested that a regular course in research ethics be added to the curriculum.

The second case study was the "Charlie West" case[4], which involves grant-writing pressures on a postdoctoral student and the ensuing temptation to plagiarize from a research proposal West had reviewed previously. We used the Michael Davis Seven Step Guide to Ethical Decision Making[1] during our discussions. As in the Jessica Banks case study[4], the discussion was relatively lively. An interesting" (and swashbuckling) concept introduced by one student was "If the material to be copied from the old proposal is only background information (as was stated in the case study), then it would be okay to copy it, since such background information is not that valuable anyway." That view, I responded, might result in interesting behaviors for houseguests. Carrying through with the same logic, the guest might walk around the host's home, asking the price of various items. "Fifty dollars? Well that is a bit expensive... Fifteen dollars, not too expensive! I think I'll steal it". Such a person might show up at Bill Gate's home with a semi-truck and a moving crew, since for Bill, most household items would be inexpensive.

The third "ethics" meeting of the MSM 885 class was held at the request of the class. In fact, we were obliged to arrange for another time and classroom for the third ethics session, since only two case study discussions had been planned, and my colleague, who taught the "regular" part of the seminar course needed all of the remaining class meetings to finish the oral research presentations required of the MSM 885 class. For the third session, I suggested that the class focus on a topic such as authorship of technical papers, plagiarism, or data management. The class picked "data management", which involves questions of who owns scientific data along with the storage and dissemination of data. To aid the in-class discussion, I selected the Fall, 1996, issue of a Michigan State University newsletter entitled "Research Integrity", since that particular issue deals exclusively with data management. The discussion was helpful, since the students became aware of both (1) University policies and (2) the "common practices in the field".

I think the ethics "addendum" to MSM 885 went fairly well, but next time I would arrange for additional class periods, so that case studies on authorship, plagiarism, and a scientific attitude in research could be included. References that I might use include Rosenblum's discussion of authorship and Grinnell's excellent text on scientific attitude.

For both the undergraduate and the graduate-level courses, the student reaction to incorporating ethics into the Materials Science curriculum was gratifyingly positive. For example, in MSM 454, I distributed the "Ethics Across the Curriculum Course Impact Survey" form provided by the IIT

NSF-sponsored Ethics Workshop mentioned in this paper's opening paragraph. Each of the fourteen students enrolled in MSM 454 turned in an Impact Survey, so at least within the course the sampling statistics could not have been better. Only two students indicated that they had any professional or business ethics in a class prior to MSM 454, and one of those two students noted that they had been unaware of ethics codes. Twelve of the fourteen students felt the course increased their awareness of "ethics issues likely to arise in your profession or job". The class responded with a unanimous "yes" to the question of whether the course had increased their "ability to deal with the ethical issues it raised". Most of the class judged the amount of ethics-related material in the course was "just the right amount".

Teaching professional ethics in engineering courses has a number of potential impacts, in terms of increasing the students' sensitivity to ethical problems, and providing problem solving schema for ethical dilemmas. But our attempts to teach ethics serve an additional and very important function: it shows that we, as engineering professionals care about ethical issues. In a paper entitled "Who Can Teach Workplace Ethics", Michael Davis[8] noted that "Each time a teacher in a professional school raises a question of professional ethics, she is an example of a member of her profession concerned about its ethics. Being concerned about the ethics of one's profession is a professional virtue."

NOTE: Some sections of this paper were excerpted (and subsequently modified and expanded) from an unpublished "end-of-Workshop" report that I wrote for the Center for the Study of Ethics in the Professions (CSEP). That report served as a preface to CSEP's "Impact Survey" forms that I distributed to my classes and returned to IIT.

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Biographical Information

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