ChE curriculum

INCORPORATING HEALTH, SAFETY, ENVIRONMENTAL, AND ETHICAL ISSUES INTO THE CURRICULUM

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INCORPORATING HEALTH, safety, environmental, and ethical issues (HSE&E) into the chemical engineering curriculum has become an important topic [1, 2], reflecting the chemical process industry's growing concern over these issues. This paper reports the results of a survey of U.S. chemical engineering departments on this matter and some details of what we are doing at the University of Alabama.

Most educators probably agree that HSE&E needs to be taught. But what is the best way to do it? Many schools include some of this type of training in the capstone senior design course (see ref. 3 for an example), but is there enough time to adequately cover the topic there? Some offer an elective HSE&E course, but with our overcrowded curriculums many schools cannot justify that approach. Also, when the course is an elective, not all ChE students will be trained. Other schools prefer to coordinate HSE&E training through examples and homework problems in the core ChE courses, but coordination of any topic throughout a curriculum is very difficult and requires the diligent effort of a designated coordinator and the full support of the department. Another problem is that several important HSE&E topics are unsuitable for inclusion in existing courses.

What are U.S. chemical engineering programs actually doing, or planning to do, at this moment? ABET recently polled all engineering programs concerning their teaching of occupational, public, and product safety and health [4]. The results were broken down according to disciplines so that the status of chemical compared to the other engineering disciplines could be seen. However, the information wasn't very specific, and it did not cover environmental and ethical concerns. The present survey is an attempt to provide information for gauging the chemical engineering discipline's success in this area and to provide concrete help for incorporating HSE&E into the curriculum.

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SURVEY DESCRIPTION

The survey was designed to find out what chemical engineering programs are actually doing, or planning to do, about teaching HSE&E issues. The questions were intentionally broad so that respondents could be free to define their own concept of HSE&E content. As a result, my interpretation of the data must be somewhat subjective, and I will try to point out the subjective comments. An example is the question of what constitutes a coordinated effort to incorporate HSE&E into the curriculum. Simple agreement at a faculty meeting does not guarantee any effort at all, but how do we know if a formal coordination plan is or is not in place? I had to interpret this based on the individual response.

The survey was sent in the fall of 1987 to the 155 U.S. departments listed in the *Chemical Engineering Faculties Directory*, and 54 (35%) of the schools responded. Since schools with an ongoing HSE&E concern might be more likely to respond, and since my interpretation is subjective, I will make no claim as to

a margin of error for this survey. I hope that the results do accurately reflect the general trends in chemical engineering HSE&E education and that they provide some useful ideas for incorporating HSE&E into your curriculum.

RESULTS

The questions are presented below as they appeared on the survey. Only the fourth question was multiple choice.

1. Does your department offer a ChE course with the major focus being health, safety, environmental, or ethical issues? If yes, please list the courses with a brief description.

36 (67%) claimed no ChE course focused on these issues. 18 (33%) offered separate courses on one or some HSE&E issues with pollution control being the most common. 7 of the 18 offered a comprehensive HSE&E course which appeared to cover at least three of the four topics.

2. Does your department have a coordinated effort to include health, safety, environmental, or ethical issues in your ChE core courses (for example, through homework problems or design experiences)? If yes, please briefy describe the program.

31 (57%) have no coordinated effort, although 10 of these 31 indicated an informal attempt to incorporate HSE&E topics. 23 (43%) do claim a coordinated effort to incorporate HSE&E into various courses, with the capstone design course being the most common, followed closely by the laboratory course. Other courses mentioned were seminar, reactor design, and separations. 5 of the 23 indicated a coordinated effort throughout most of the core courses.

3. Does your department have specific plans to incorporate these topics into the curriculum within the next five years? If yes, please briefly describe the plans.

10 (19%) plan to modify their curriculum in some way to include some or more HSE&E content. The plans ranged from inclusion of HSE&E in the capstone design course to creation of an elective HSE&E course. 44 (81%) have no plans to do anything different, but many of these already are making significant efforts.

4. Is there a consensus within your department whether such topics are best:

a. included as a separate course (required or elective)?
5 (9%)

b. coordinated as problems within the existing courses?
18 (33%)

c. left for industrial training?
2 (4%)

d. no real consensus.
29 (54%)

Some responses were split between two options and were counted as half for each answer. Several participants expressed personal opinions but indicated that there was no departmental consensus.

[HSE&E] is far too important a topic . . . [for] a "hit or miss" incorporation in the core curriculum . . . the student must be introduced to the concept of making socially responsible professional decisions in addition to being trained . . . on how to design a properly-sized relief valve.

The majority of schools—whether by deed, plans, or simply opinion—lean toward incorporating HSE&E into the existing core courses, and the most popular courses seem to be the capstone design course and the laboratory. Not many actually incorporate it throughout the curriculum. Only a handful offer or are planning to offer a comprehensive HSE&E course.

Perhaps the most surprising result is that most departments do not plan to increase the HSE&E content of their curriculum. Of course, many already have some HSE&E content, but in my opinion at least half of those which do not intend to increase HSE&E content currently have insufficient coverage to meet the spirit of ABET HSE&E criteria.

SELECTED HSE&E IDEAS

The most popular option for teaching HSE&E is by incorporating it into the capstone design course. Several schools (for example, the University of Washington) dedicate several of the initial design lectures to specific HSE&E topics, and at the University of New Mexico weekly 15-minute mini-lectures on HSE&E topics are interspersed in the design class [3]. An HSE&E section is required in the design reports of other schools.

The unit operations laboratory is also a popular class in which to teach safety. At one university, the school's health and safety office lectures the students on safety and then provides a competency test before the laboratory course can proceed.

Probably the hardest option (but maybe the best) is to incorporate HSE&E throughout the curriculum. At the Massachusetts Institute of Technology plans are being considered to reorganize several core courses around case studies that place emphasis on HSE&E concerns. The University of Arkansas, under contract with the Center for Chemical Process Safety, has prepared a collection of HSE&E problems for a variety of ChE core courses. Marvin Fleishman has also recommended HSE&E topics that could be incorporated in several ChE core courses [2].

A number of schools offer dedicated courses on HSE&E topics. Some of these are "single-topic" courses like pollution control or engineering ethics. Several others offer a course which covers some com-

bination of HSE&E topics. The most popular topics seem to be those that cover occupational health, personal safety, and loss prevention. Ethics is sometimes included explicitly and is most probably implicitly covered. The course contents are not uniform, are rapidly evolving, and several syllabi are being used. An interesting technique used in the HSE&E course at Rutgers University is the requirement of a term paper analyzing a chemical process from raw materials handling through the chemical process itself, to product distribution and to ultimate disposal. This reflects the current "cradle to grave" responsibility of chemical producers for their products.

Some schools have made use of guest lecturers from industry or government agencies and have videotaped the lectures for future use. NIOSH and OSHA lectures were videotaped at West Virginia University [5], and five 2-hour lectures were telecast to Wayne State University from BASF corporation on a variety of HSE&E topics [6]. The latter are being prepared as a study guide to be sold through the AIChE. Many schools regularly include a speaker on HSE&E issues in their graduate seminar.

ALABAMA'S PROGRAM

In the spring semester of 1988 we offered, for the first time, an elective course entitled "Health and Safety in the CPI," a survey of safety (both personal and loss prevention), health, environmental, and ethical issues. It is intended for chemical engineering and chemistry students, although we also hope to attract students from other technological fields. The course description reads:

> **Historical, legislative, and technical aspects of safety, health, environmental, and ethical issues. Develop skills to assess, design to prevent, and mitigate health and safety problems in the chemical process industry.**

Why try to teach all this is one course? A student should be introduced to all four subjects in order to be prepared for responsible professional decisions, but the subjects weren't being adequately covered, and we only had room for one more elective course. The subjects group together naturally, having a common feature; they all have aspects which are reasonably hard to quantify and involve some subjective thinking.

It is unrealistic to expect to develop expertise in any specific topic and still cover such a broad array of subjects. For instance, we discuss hazard and operability (HAZOP) analysis and go through a practice problem, but leave detailed training in HAZOP analysis for industrial employers. Student surveys indicated that most students were confronted with these issues for the first time in the course and that their awareness was radically increased, indicating that the course accomplished my primary goals.

The syllabus for the course is shown in Table 1. A variety of teaching methods and materials are used,

TABLE 1
Course Syllabus

		# Lect.
1.	**Introduction**	
	A Introductory lecture: The Engineer and Society	1
	B "Technology and the Law," OSHA lecture taped at West Virginia University: discussion	1
	C *Acceptable Risks,* ABC movie; discussion	2
2.	**Safety**	
	A Personal Safety	
	1. General discussion; HAZCOM and Kletz's "What Went Wrong?" as guides	1
	2. Lecture by Safety Director from Hunt Oil	1
	3. Laboratory safety movies; discussion	2
	4. Actual laboratory inspection of University Labs; discussion of inspection reports	2
	B Loss Prevention	
	1. Types of accidents; Kletz's "What Went Wrong?"	2
	2. Prevention technology - pressure relief devices, plant layout, fail-safe systems, *etc.*	1
	3. IChemE case study slide shows; discussion; students try to figure out how accidents happened	2
	C Hazard Analysis; Center for Chemical Process Safety material; analyze chemical processes, predict potential problems, suggest preventative measures	2
3.	**Health**	
	A Government regulations; OSHA and NIOSH lectures taped at West Virginia University	1
	B Toxicology; *Carcinogens, Anticarcinogens, and Risk Assessment,* video tape by Professor Ames (UC-Berkeley) for the Council for Chemical Research	1
	C Prevention technology; process, isolation, protection	1
	D Case studies: asbestos, vinyl chloride, benzene, *etc.*	2
	E *Wrath of Grapes,* United Farm Worker's video on pesticide abuse; discussion; critical analysis of information given	1
4.	**Environment**	
	A Government regulations; EPA, Superfund, *etc.*	1
	B Types of pollution; air, water, ground water, land	1
	C Pollution technology; aerobic digestion, incineration, scrubbers, *etc.*	2
	D Case studies: Willamette river cleanup, Rhine River spill, Monongehela River spill	1-2
	E *Silent Spring / Silent Spring Revisited:* discussion	1-2
5.	**Ethics**	
	A Engineering codes of conduct and introduction	1
	B Selected readings from *The Ethics Reader*; discussion	1
	C *Chemical Engineering* ethics surveys; discussion	2
6.	**Term Project Reports**	5
	TOTAL	**45**

Note: As a second-time course this syllabus will certainly be modified throughout the semester: Please give me input on the course content. I welcome your comments!

TABLE 2
Course Resources

INTRODUCTION
- Hearl, F. J., P. E., *Technology and the Law,* NIOSH seminar videotaped at West Virginia University, loaned by Professor Wallace B. Whiting
- *Acceptable Risks,* ABC-TV movie originally broadcast on Sunday, March 2, 1986

SAFETY
- Kletz, T. A., *What Went Wrong: Case Histories of Process Plant Disasters,* Gulf Pub. Co., Houston, 1985
- Lees, F. P., *Loss Prevention in the Process Industries,* Butterworths, Boston, 1986
- "Guidelines for Hazard Evaluation Procedures," Center for Chemical Process Safety by Batelle Columbus Division, AIChE, New York, 1985
- Wadden, R. A., and P. A. Scheff, *Engineering Design for the Control of Workplace Hazards,* McGraw-Hill, New York, 1987
- "Loss Prevention," Chemical Engineering Progress Technical Manual, AIChE, New York, various issues
- Whitmyre, G., and R. L. Long, "Guide to Safety in the Laboratory for Chemical Engineers," New Mexico State University, 1987
- Stull, D. R., "Fundamentals of Fire and Explosion," *AIChE Monograph Series,* **10**, (73), 1977
- *Hazard Workshop Modules: Fires and Explosions,* training slide show prepared by *IChemE,* 1987
- "Loss Prevention Bulletin," *IChemE,* various issues

HEALTH
- A variety of standard industrial hygiene texts
- *Fighting Workplace Cancer,* United Auto Workers, slide tape show
- Silverstein, M., M.D., "The Case of the Workplace Killers: A Manual for Cancer Detectives on the Job," United Auto Workers, 1980
- "Current Intelligence Bulletin," NIOSH, various issues
- Ames, B., *Carcinogens, Anticarcinogens, and Risk Assessment,* videotape for the Council for Chemical Research, 1987
- *Wrath of Grapes,* videotape by the United Farm Workers

ENVIRONMENT
- A variety of standard pollution control engineering texts
- Hanna, S. R., and P. J. Drivas, *Vapor Cloud Dispersion Models,* Center for Chemical Process Safety, AIChE, New York, 1987
- Myhre, R., *Double Alkali Flue Gas Desulfurization: The CIPS Experience,* Engineering Case Library, Washington Internships for Students of Engineering Program, 1983
- Carson, R., *Silent Spring,* Houghton Mifflin, Boston, 1962
- Marco, G. L., R. M. Hollingworth, and W. Durham, Eds., *Silent Spring Revisited,* ACS, Washington, DC, 1987

ETHICS
- Flores, A., ed., *Ethical Problems in Engineering,* Vol. 1, The Center for the Study of the Human Dimensions of Science and Technology, Troy, NY, 1980
- Baum, R. J., ed., *Ethical Problems in Engineering,* Vol. 2, The Center for the Study of the Human Dimensions of Science and Technology, Troy, NY, 1980
- "Suggested Guidelines for Use With the Fundamental Canons of Ethics," Accreditation Board for Engineering and Technology, New York, 1985
- Vesilind, P. A., "Rules, Ethics and Morals in Engineering Education," *Eng. Ed.,* 289, February, 1988
- Berube, B. G., "A Whistle-Blower's Perspective of Ethics in Engineering," *Eng. Ed.,* 294, February, 1988
- Matley, J., and R. Greene, "Ethics of Health, Safety and Environment: What's Right?" *Chem. Eng.,* **40**, March 2, 1987

including traditional lectures, discussion groups, video tapes, slide shows, guest speakers, and field trips. Resources are widely scattered but available. Some resources that I use are listed in Table 2. Some of them are traditional (from the AIChE, IChemE, CCPS, *etc.*), and some are more non-traditional. The latter include the ABC movie, *Acceptable Risks*, and the United Farm Worker's documentary, *Wrath of Grapes*. These films impose a dramatic and emotional element to safety and health discussions, as *Silent Spring*, by Rachel Carson, does to the environmental issue. This is entirely appropriate and results in remarkable classroom discussions.

We cannot expect every student to receive HSE&E training with this effort alone since this is an elective course. Therefore, we initiated a coordinated effort to intersperse HSE&E training throughout the entire chemical engineering core curriculum. The primary tool was the CCPS example problems compiled at the University of Arkansas, but not many of the problems were actually used the first time around. One benefit of this survey was obtaining new and diverse ideas from my colleagues for accomplishing the HSE&E incorporation.

OBSERVATIONS

I sensed a general agreement that the university has a responsibility to provide some training in HSE&E issues. It is far too important a topic to relegate to a few lectures in the capstone design course or a "hit or miss" incorporation in the core curriculum. It is also more than a strictly technological topic; the student must be introduced to the concept of making socially responsible professional decisions in addition to being trained, for example, on how to design a properly-sized relief valve.

I believe we will eventually see the need for a *required* HSE&E course. Most present HSE&E offerings are elective and so by definition do not meet this need for all students. The scope and content of the HSE&E course will evolve but there are too many important topics that cannot be adequately covered within another course. How this HSE&E course will fit into a crowded curriculum will be a hotly debated issue!

Incorporating HSE&E topics within the core curriculum should be a concurrent activity. This will gradually come as more faculty are impressed with the need to teach HSE&E and as more resources specific to the various core courses become available. To facilitate the incorporation, each department should identify a dedicated individual or committee to continuously coordinate the topics taught, collect and dis-

seminate resource material to the faculty, and to monitor progress.

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3. Kauffman, D., "Health, Safety, and Loss Control Topics in the Senior Design Courses," *Plant/Operations Prog.*, **6**, 73 (1987)
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SCIENCE AND ETHICS

Continued from page 67.

state of the art and future directions of ethics in engineering and sciences. There is very little of substance in this report that could be useful in teaching. One author reports a brief personal code of ethics attributed to John Last of the *Canadian Journal of Public Health*:

> **Be honest.**
> **Be truthful.**
> **Be fair to collaborators.**
> **Uphold the honor, dignity, and credibility of your field.**
> **Act and write in the public interest.**
> **Save trees.**

This quote might provide an interesting springboard for classroom discussions of the meaning and utility of engineering codes of ethics. Some vague suggestions were made on changes needed in corporate or public policy, but, in general, these comments were limited to identification of the problems; specifics on what the changes should be and how such changes could be implemented were not addressed.

The majority of the material was written by participants in this field, for participants in this field, and in the jargon of this field. The symposium papers submitted deal primarily with problems of defining the structure of this area, and therefore provide little of use to technical personnel. It is interesting to note that the major challenges in this field were identified to be: 1) the introduction of EVS (Ethics and Values Studies) into technical education; 2) the need to have EVS evolve from a passive role to an active role (*i.e.*, transition from conducting impact studies to influencing public policy); and 3) the need to obtain more funding for research. One of the laudable goals identified for education by one contributor is the collection of educational materials that would emphasize development of critical thinking and that could be used easily in grades K-12 as well as in universities.

This is a profoundly disturbing collection of papers and working group reports because it reveals an entire field devoted to ethics in science and engineering, funded by NSF, but dominated by a group of people who exhibit no knowledge of engineering and science or of how technical people work within the corporate structure. I found it disturbing that none of the participants addressed the extent to which decisions on application of technology are made by people who do not have technical training, a critical omission when studying the ethics of technology in a society so dominated by profit as "the bottom line." The comments of some of the contributors reflect a surprising bias against the technical fields they are studying. The following excerpt from a section discussing the need for new teaching methodology provides an example (emphasis is mine):

> **There needs to be more creative approaches to the dissemination of EVS/STS (Ethics and Values Studies/studies in Science, Technology, and Society). One of the most troublesome aspects of EVS/STS dissemination has to do with college teaching. In many cases, philosophy departments send their youngest and least experienced faculty to tell students in science and engineering how to be good people. Often those faculty have no idea what the real problems of the field are; worse, they proceed to brand the particular scientific or engineering field as a social evil. They are unprepared to address the real ethical issues in the field or to help students with ethical problem solving. *It does no good to tell people that their field is bad without showing them practical ways to improve practice in their field.***

Of course, no field, including those in the sciences and engineering, is inherently bad. Comments like these, made by a professor in a psychology department, reflect a profound lack of understanding of the nature of engineering and science. Such comments also underscore the need for a greater activity by our professional societies (*e.g.*, AIChE) in the area of public policy. The development of the field of ethics and value studies in science and engineering in departments of philosophy, psychology, and/or social sciences is, in part, a response to the vacuum caused by the reluctance of technical people to get involved in ethical issues. It is vital that leadership in this area be provided by engineers and scientists who can be knowledgeable in *both* the technical and the managerial aspects of the problem. ❐