Chemical Engineering and Society—A Response to Constituency Concerns

Ronald E. Terry, W. Vincent Wilding
Chemical Engineering
Brigham Young University

Abstract — As members of the faculty of the Chemical Engineering Department at Brigham Young University (BYU), we have used feedback from constituency groups to assist in the design of a new course called Chemical Engineering and Society. These constituency groups consisted of students, alumni, our own faculty, members of faculty of other engineering programs, employers of companies that hire our students, an external advisory board, and a student advisory board. The new course treats three topics that are fundamental to responsible engineering practice. These are ethics, the environment, and safety. Course objectives include the following:

1. *To understand and commit to sound ethical behavior;*
2. *To understand, commit to, and gain experience in environmentally responsible engineering;*
3. *To understand, commit to, and gain experience in engineering safety.*

The material in the new course lays a foundation for design problems interspersed throughout later courses in the chemical engineering curriculum.

The purposes of this paper are: 1) to demonstrate the interaction and contributions of our constituency groups in the development of our educational plan to respond to EC2000; and 2) to describe the new course and its educational goals and benefits for our chemical engineering students.

Introduction

During the development of an educational plan for students in the Chemical Engineering Department at Brigham Young University, we, along with our faculty colleagues, identified several topics that we felt were being treated insufficiently in our curriculum.[1-2] Many of these were listed in ABET's Engineering Criterea 2000 as desirable student outcomes. These included engineering ethics, industrial and laboratory safety issues, environmental concerns, leadership and teaming principles, and other issues involving how chemical engineering relates to technology and society. We wrote a series of educational goals, attributes, and competencies for the general topics of ethics and professionalism, environment, and safety that we proposed to be included in the undergraduate curriculum. We then asked for feedback from our constituencies including our colleagues and an external advisory board regarding these proposed changes to the curriculum. The external advisory board consisting of one academic person and 4 industrial representatives reviewed our proposal and made some excellent suggestions and even volunteered material for use in teaching these concepts including specific topics in safety and

environmental issues. From the discussions with our advisory board and from the formulative discussions within our own faculty, we determined that an effective and efficient way to teach ethics and professionalism, environment, and safety would be to develop a course to treat these topics in a fundamental way and then build upon the foundation of that course by incorporating topic-specific lecture material and examples into subsequent courses.

The new course, which we specified as a three-hour course and titled *Chemical Engineering in Society*, was slated for the first semester of the junior year so that it will come after the sophomore-level material balance course, but will precede most of the core chemical engineering courses. As a first pass the course was fairly equally divided into three sections: ethics, environment, and safety. Future offerings may adjust this distribution. Following is a discussion of the genesis of the course.

Ethics and Professionalism

The material for this part of the course was taken from an engineering ethics course that has been taught at Brigham Young University for the last 6 years. The ethics material contains a dilemma resolution/decision-making process built on a firm, morals-based value system. The professionalism component focuses mainly on the importance of engineers being able to function on teams. Table 1 contains an outline of the material discussed during this portion of the new course.

Table 1. Topics in Ethics and Professionalism

Value based system
Dilemma resolution procedure
Study the dilemma
Consider various resolutions and their consequences
Select and sanction the resolution
Implement and evaluate the resolution
Leadership principles – making the public life consistent with the private life
Teaming issues
Understanding yourself – Myers-Briggs Type Index (MBTI)
Understanding others – Use of the MBTI in team settings
Technology and society

Environment

There were difficult decisions to be made concerning the environmental topics to be covered in this course since there would only be about 12 class periods devoted to the subject. The quandary is between depth and breadth. However, we did have some experiential background to draw from.

Since 1996 the chemical engineering department at BYU has offered a course entitled "Environmental Engineering for Chemical Engineers." This is a rather unwieldy title, but since BYU's Civil Engineering Department had years earlier adopted the "Environmental" moniker,

we felt it important to emphasize the chemical nature of the material. This course was taught mainly to juniors and seniors with a few graduate students and civil engineering majors thrown in. Table 2 shows the list of topics covered in this course.

Table 2. Topics in 3-Hour "Environmental Engineering for Chemical Engineers" Course.

Historical Aspects of Environmental Engineering
Environmental Ethics
Environmental Legislation
Fate and Transport
Toxicology
Risk Assessment
Ozone Depletion
Global Warming
Pollution Prevention and Waste Minimization
Design for Waste Minimization
Hazardous Waste
Physico-Chemical Treatment
Biological Treatment
Stabilization and Solidification
Thermal Processes
Land Disposal
Remediation

Recently, this course has used the text Hazardous Waste Management by LaGrega et al. Supplementary material on many of the topics was drawn from other sources.

During the summer of 2000 one of the authors attended the Green Engineering Educators Workshop held at the University of Nevada-Reno and procured much valuable training and material. Then in 2001, Green Engineering, by Allen and Shonnard, which grew out of the Green Engineering workshops, was published. This text proved to be a valuable resource for the course.

The "Environmental Engineering for Chemical Engineers" course and the Green Engineering material provided the basis for the environmental portion of the new course. Table 3 shows the environmental topics that were finally selected for the course.

Table 3. Environmental Topics included in New Course.

Environment responsibility/roles of chemical engineers/ethics
Chemistry – structure and environmental properties
Energy
Fossil Fuels
Nuclear
Renewables
Environmental issues
Global environmental issues
Ozone depletion
Global warming
Fate and transport
Hydrologic cycle
Transport/reaction mechanisms
Darcy's law
Terminology and characteristics (e.g., vadose zone, aquifer, LNAPL, porosity)
Toxicology
Measurement
Fate of toxins in body
Dose-response, threshold
Toxic effects mechanisms
Cancer
Risk and risk assessment
Environmental legislation
Legislation, US Code, CFR
Major acts – general understanding of content and intent - emphasis on RCRA, CERCLA
Product and process engineering for waste minimization (P2)
Life-cycle analysis
Waste treatment and remediation

Safety

There have been bits of safety material in our curriculum for many years, but the treatment was superficial and sporadic. During the summer of 2000 one of the authors attended the SACHE Faculty Workshop held at the BASF plant in Wyondotte, MI. This workshop provided much valuable material and training for infusing safety into the chemical engineering curriculum. This experience and the recognized need for a more thorough and rigorous treatment led to the incorporation of a significant quantity of safety material into the senior design course. Table 4 shows the topics that were incorporated into this course.

Table 4. Safety Topics Included in the Senior Design Course, 2001.

Safe Processes/Practices
Reliefs
Bonding/Grounding
Lockout/Tagout
Inherently Safe Design

However, the design course was already bursting at the seams in terms of content material, and so the prospect of moving this material to an earlier course and expanding the treatment was very appealing. The main reference for the safety material incorporated into the new course is Chemical Process Safety: Fundamentals with Applications, by Crowl and Louvar. Many SACHE and CCPS materials were valuable as well. Table 5 shows the safety topics selected for the new course.

Table 5. Safety Topics included in New Course.

Chemical engineering safety responsibility – Code of ethics
Inherently dangerous yet safe industry
Causes of failure
OSHA – Goals
Safety – mechanical, electrical
Health – chemical
MSDS – information
NFPA labels
Exposure calculations (TWA)
Properties
Flash point definition and estimation method
Flammability limits
Autoignition temperature
Materials compatibility
Fires and explosions
Vapor cloud / Boiling liquid expanding vapor explosions
Prevention/minimization of consequences
Inerting, Purging
Static electricity
Calculations/Bonding and grounding
Reliefs – Location, Types
Lockout/tagout
Hazards identification and risk assessment
Process diagrams
HAZOP
Fault tree analysis
Probability
Inherent process safety
Risk management strategy
Design approaches

Observations about the Initial Course Offering

The new course (ChEn 311) was offered for the first time fall semester of 2001 to a large class consisting of juniors and seniors. Although assessment of the effectiveness of the course is still underway, some general lessons have already been learned.

Many students were frustrated with the lack of a textbook for the course. We knew this would be a problem before the course began, and are working to remedy that for future offerings of the course. Some students felt that the course was somewhat disjointed with three disconnected subjects, and a few students failed to appreciate the value of treating ethics in the engineering curriculum. We are already working to incorporate case studies that include all three aspects of the course into future offerings.

In order to make room for the course in the curriculum the number of hours of technical electives, including advanced chemistry, were reduced. A couple of our department faculty members felt this price was too high, and we considered other means of addressing these topics, such as simply integrating these topics throughout the existing curriculum. However, we felt a separate course was needed to establish these subjects as foundations to good engineering practice rather than as afterthoughts. In addition to the course itself we are in the process of developing problems to be incorporated into later courses to build on the foundation laid in this course.

This new course will provide students with a basis for dealing with ethics, environment, and safety in chemical engineering practice as it helps students develop the desired commitments and competencies.

Conclusion

A new course has been developed that includes topics in engineering ethics, industrial and laboratory safety issues, environmental concerns, leadership and teaming principles, and other issues involving how chemical engineering relates to technology and society. The work of integrating the material into the other courses in the curriculum is still to be done. We believe that the course and additional reinforcement in later courses will help students develop understanding of, commitment to, and problem solving ability associated with these important competencies.

REFERENCES

1. Wilding, W.V., Harb, J.N., Terry, R.E., and Hecker, W.C., "Maximizing the Benefits of Developing an Educational Plan to Meet the ABET 2000 Criteria", Proceedings of 1999 ASEE Annual Conference, Charlotte, North Carolina, June 20-23, 1999.

2. Terry, R.E., Harb, J.N., Hecker, W.C., and Wilding, V.W., "Definition of Student Competencies and Development of an Educational Plan to Assess Student Mastery Level", in print in *the International Journal of Engineering Education*.

RONALD E. TERRY

Ron Terry is a Professor of Chemical Engineering at Brigham Young University. He has conducted scholarly work and published numerous articles in engineering education. He is an active member of the ERM Division within ASEE. He holds B.S. and Ph.D. degrees in Chemical Engineering from Oregon State University and Brigham Young University, respectively.

W. VINCENT WILDING

Vincent Wilding is an Associate Professor of Chemical Engineering at Brigham Young University. His research interests include thermophysical properties, phase equilibria and environmental engineering. He received his B.S. degree in Chemical Engineering from Brigham Young University in 1981 and his Ph.D. in Chemical Engineering from Rice University in 1985.