TEACHING FIRST-YEAR STUDENTS THE FUNDAMENTALS OF ENGINEERING

Michael Hagenberger[1], Barbara Engerer[2], and Douglas Tougaw[3]

[1] Valparaiso University, Valparaiso, IN; Email: Michael.Hagenberger@valpo.edu
[2] Valparaiso University, Valparaiso, IN; Email: Barbara.Engerer@valpo.edu
[3] Valparaiso University, Valparaiso, IN; Email: Doug.Tougaw@valpo.edu

1. INTRODUCTION

The first semester of a student's academic career is always very important, and it may be even more important for an engineering student. From increasing academic rigor to increased freedom to make important life-affecting choices, the first semester of an engineering program holds great opportunity to change a student's life. Along with this high degree of importance comes a high degree of flexibility, because there are many different ways in which a first engineering course can be structured and taught. Each of these different philosophies has its benefits and liabilities, and optimizing the first-semester engineering course is still a very active area of curricular research.

In this paper, we will first present an overview of the many different philosophies being used to teach first-year engineering students are programs throughout the country, highlighting the rationale for each. Next, a summary of the previous first-semester programs at Valparaiso will be presented, along with a discussion of the revision process that took place over a period of many months. Finally, we will describe the resulting course, which was taught for the first time in the fall semester of 2005, including an assessment of its effectiveness and lessons learned for future improvement of the course.

2. PHILOSOPHIES IN FIRST-YEAR ENGINEERING EDUCATION

One traditional approach for first courses in engineering is to provide students with knowledge of the different engineering disciplines necessary to select a major and, eventually, a career. Courses at universities such as Vanderbilt (Rowe and Mahadevan-Jansen, 2004) and Purdue (LeBold, *et al.*, 1999) provide such background knowledge, helping their students to make an informed decision about their choice of major. Frequently, such courses are designed in a modular structure, such that students can complete different modules and hands-on projects based on their particular interests.

Other programs (Pierson and Suchora, 2004; Katehi, *et al.*, 2004) devote at least a part of their first-year program to instilling in students the ability to use computational tools to solve engineering problems. From spreadsheet skills to high-level language programming, such skills will be important for all disciplines, but especially so for electrical and computer engineering students.

The introduction of ABET Engineering Criterion 2000 created many new expectations on engineering programs, and many of those programs responded by changing their introductory courses. Many universities (Pierson and Suchora, 2004; Katehi, *et al.*, 2004; Hirsch, *et al.*, 2002; Larochelle, *et al.*, 2004; Qammar, *et al.*, 2004; Diefes-Dux, *et al.*, 2004; Reardon, 1999) increased the emphasis on engineering design and engineering analysis in this first course, including the introduction of hands-on design projects to be completed by individual students or teams of students. Some universities created courses that explicitly attempted to increase their students' teamwork skills (Whalen, *et al.,* 2005), while others sharpened their focus on improving their students' problem-solving skills (Katehi, *et al.,* 2004) and creative and critical thinking skills (Catalano, 2004). Perhaps the most difficult mandate of EC2000 is that students be able to work effectively in multidisciplinary teams, which has led universities such as Purdue to create courses that build interdisciplinary connections in their students' minds. (Diefes-Dux, *et al.,* 2005)

Many emerging philosophies in first-year engineering education have grown out of fundamental pedagogical research that supports a holistic approach to engineering education. For example, a great deal of work has been done to investigate and confirm the usefulness of learning communities, which are being implemented at several universities.(Katehi, *et al.*, 2004; Rutaw and Mason, 2005) Other universities, such as Texas A&M and the Air Force Academy, are working to provide their students with an integrated curriculum that combines engineering, mathematics, and science into one course sequence that helps students to more effectively see the interconnections among those topics. (Froyd and Ohland, 2005; Pines, *et al.*, 2002; Brandt, *et al.,* 2004)

Another important area of pedagogical research that has benefited first-year courses is development of a student-centered structure in which the instructor is more of a guide than a source of knowledge. Courses at universities such as Virginia Tech and Bucknell have created such an environment in which in-class hands-on projects are used to illustrate the material, holding the students' interest and helping them to more effectively learn important engineering concepts. (Connor and Mazahn-Kampe, 2002; Gardner, *et al.*, 2002; Pierson and Suchora, 2002; Vigeant, *et al.,* 2004) Still others have used students' natural inquisitiveness to help them develop the skills necessary to investigate, model, and analyze very complex systems. (Diefes-Dux, *et al.,* 2005; Craig, *et al.*, 2003; Leland, *et al.*, 2005)

3. FOCUSING ON THE FUNDAMENTALS OF ENGINEERING AS A TOOL FOR TEACHING FIRST-YEAR ENGINEERS

Although some of these philosophies do appear to be mutually exclusive, an optimal first-semester course would benefit from adopting the best characteristics of each. By balancing these different philosophies, it may be possible to design a course that is more effective than any one philosophy could have been. We have attempted to design such a balanced course, modeled after work done at Purdue University (Katehi, *et al.,* 2004), that helps students to learn the fundamentals of each engineering discipline and build interdisciplinary connections among those disciplines, and we do so through a balance of traditional lecture and hands-on laboratory and design experiences.

By focusing on the fundamental principles of each engineering discipline, this course will achieve several objectives. First, it will increase the students' knowledge of the interconnections among the different engineering disciplines, which will help them to be more effective in multidisciplinary teams. Second, it will help prepare them for subsequent courses in each of these fundamental disciplines by building a foundation for future work. Third, it will help the students to see the most important ideas in each field, which will prepare them to make an informed decision about their major. Finally, introducing these topics will require the academic rigor of the course to increase, which will more effectively prepare students for the more difficult material to come in subsequent semesters.

This focus on the fundamentals of engineering was applied to the first-semester engineering course required of all 120 incoming students in the College of Engineering at Valparaiso University. These students were broken up into five sections of approximately 24 students each. The only pre-requisite for the course was enrollment as an engineer or a pre-engineer, and students in the course were typically also enrolled in calculus, physics, and a five-credit integrated humanities/social science core course. Students in this course were typically proficient with mathematics through trigonometry, and some differential calculus was appropriate in the second half of the semester.

4. WHAT ARE THE FUNDAMENTALS OF ENGINEERING?

The faculty involved in designing the course selected 26 topics that they felt composed the fundamental concepts of engineering. Each department made lists of topics that they thought were critical for their students, and these were then combined and edited. The topics selected are shown in Table 1. The first seven topics are general in nature: engineering analysis, engineering design, probability and statistics, teamwork, library research, engineering communication, and accuracy and precision. These topics include material present in a typical freshman course: teaching students how to set up and work a problem, how to present the material in an organized fashion, and give the results to the correct accuracy. They also introduce concepts from ABET Criteria including teamwork and communication. Library research was done on an area of emerging technology; this information was presented in a paper and an oral presentation at the end of the semester.

Table 1. Topics Covered

1. Engineering Analysis
2. Engineering Design
3. Probability and Statistics
4. Teamwork
5. Library Research
6. Engineering Communication
7. Accuracy and Precision
8. Voltage and Current
9. Power and Energy
10. Mechanics - Statics
11. Material Properties
12. Mechanics - Dynamics
13. Structural Engineering
14. Transportation
15. Digital Logic
16. Electromagnetic Fields
17. Motors
18. Manufacturing
19. Pneumatics
20. Environmental Engineering
21. Fluids
22. Vibrations
23. Thermodynamics
24. Heat Transfer
25. Programming
26. Project Management

The remaining topics were discipline-related. Priority was given to topics deemed important by more than one department, such as statics or material properties. Some topics, for example motors, were included because they are useful for all disciplines. Many topics built on others. “Power and Energy” continued on from “Voltage and Current,” while “Material Properties” built upon “Statics,” and “Structural Engineering” continued on from “Material Properties.”

Some topics changed during the process. One early topic was graphing, which was combined with writing and presentations to form “Engineering Communication.” Another early topic was “Design Methodology and Safety Factors,” which was broadened into “Probability and Statistics” with design safety factors used as a prime example. The faculty also considered “Mechatronics,” which was simplified to “Pneumatics,” using pneumatic valves to operate a robotic hand.

In all topics, the interdisciplinary nature of engineering was emphasized. Earthquakes, radio waves, and engines were all discussed in “Vibrations,” and “Transportation” discussed roads, automobiles, and traffic signals. Many of the topics are broad enough for an entire course, but the faculty always attempted to focus on the key elements of each topic that were considered most fundamental. In “Environmental Engineering,” for example, the lectures discussed the entire field, but the laboratory experiment focused only on water treatment. In “Statics,” we set up problems using free body diagrams without solving them, while “Thermodynamics” included a few simple examples of First Law analysis plus some brief discussion of entropy. The time constraints imposed by just 26 two-hour sessions to cover the entire field of engineering led to many critical judgments about the relative importance of different topics and many energetic discussions of their relative merit.

5. INTEGRATING ACTIVE LEARNING EXERCISES INTO THE COURSE

Throughout the semester, students participated in a wide range of active learning exercises, including laboratory experiments, in-class projects, and computer exercises. In each case, these activities were selected to illustrate a particular concept from the lecture and to provide an opportunity for students to develop their teaming skills.

5.1. A Vibrations Exercise

During the “Vibrations” lecture, students performed tests on two springs with different load deformation characteristics to find the natural frequency and the spring constant of each spring. Using their experimentally determined spring constant, the students calculated the theoretical natural frequency of each spring and compared that to the one that they had measured. The equipment required for this exercise was portable, allowing the tests to be performed in the classroom.

5.2. Bridge Design Competition

West Point Bridge Designer, a program develop by the United States Military Academy, was used in the “Structural Engineering” unit. This program allows students to design a bridge within specific project constraints. After each iteration, students can view the efficiency of each member in the structure based on computer-calculated loads and member capacities. In addition, the program calculates the cost of their design based on the material, connections, and site costs. The students were encouraged to minimize the cost of their structure to receive maximum credit for the assignment, and they were further motivated by a course-wide bridge design competition. This computer exercise illustrated principles of structural design, including the relationship to cost, in a way that would be difficult in a lecture and in a way that stimulated the intellectual curiosity of the students. In addition to illustrating the concepts of structural design, the exercise built on the concepts discussed in the units on statics and material properties.

5.3. Electromagnetic Fields Demonstrations

For the “Electromagnetic Fields” unit, twelve demonstrations were used to illustrate concepts that are often difficult for many students to understand. The demonstrations included electromagnets, permanent magnets with iron filings to show lines of a magnetic field, and simple DC motors to crank solenoids. After each concept was discussed, the instructor performed the appropriate demonstrations to visually illustrate the abstract concept to the students. Students were also encouraged to experiment with the demonstration tools as they were passed around the classroom.

5.4. Heat Transfer Calculations

A final type of active learning exercise was to assign problems to be completed in class, typically in groups, and with the guidance of faculty members and upper-class student mentors. For example, after describing radiation in the “Heat Transfer” unit, students were asked to work in pairs a radiation problem involving heat loss of an electronic circuit in a case. When all of the groups had completed the exercise, one group was selected to work the problem on the board and explain their solution to the rest of the class. This provided an opportunity for the instructor to review the students' problem solving techniques, understanding of the concept, and communication skills. Since this unit was the last before Thanksgiving, and the diagram for the problem resembled an object in an oven, that in-class exercise was centered on a calculation of the emissivity of a turkey.

6. INTEGRATING LABORATORY EXERCISES INTO THE COURSE

A majority of the topics covered in the first-year course incorporated a lab experience for the students. The format of the labs varied from topic to topic and included: 1) hands-on experiments; 2) demonstration laboratories; and 3) computer lab exercises.

6.1. A Fluids Experiment

A hands-on experiment was developed for the fluids lesson and utilized relatively simple set-ups that were constructed from readily available materials. The set-up included a vertical four inch diameter PVC pipe on a wood base that had holes drilled at equal spacing along the height of the pipe, and a manometer constructed of simple fittings and a clear plastic pipe to monitor the elevation of the water in the pipe. The pipes were filled with water and the students were asked to measure the flow rate out of one of the holes in the pipe while keeping the water elevation in the pipe constant. In the lesson prior to the lab, the students learned three methods of calculating flow rates, including using Bernoulli's equation, using particle dynamics, and by simply recording the time required for a fixed amount of water to be expelled from the pipe. The primary objective of the lab was to provide the students with an opportunity to apply the theoretical concepts discussed in the lesson prior to the lab. In addition to performing the experiments, students were asked to perform their calculations on the board. Requiring the students to present their results in class led to discussions regarding potential sources of error in data collection, accuracy of the different methods used, and differences between theoretical models and experimental results.

6.2. Material Properties Testing

A demonstration laboratory was developed for the lesson on material properties that included compression tests on standard concrete cylinders and tensile tests on mild steel specimens. The primary objectives of this lab were to demonstrate the concepts of brittle versus ductile behavior of materials, calculate stress and strain, and calculate elastic material stiffness, which were concepts that were presented in the lesson prior the lab. The load data for the concrete specimens and the load and deformation data for the steel specimens were collected in each section of the class and provided to the students in all sections. The students were then asked to analyze the data, including plotting the stress-strain relationship for steel specimens tested during their section, determining the modulus of elasticity for steel from their plot, and the calculation of the ultimate stress for each concrete cylinders. In an effort to build on the probability and statistics lesson from earlier in the semester, students were supplied with the concrete data from all the sections and were asked to perform simple statistical calculations and provide a recommendation as to the design strength of the concrete tested.

6.3. A Project Management Exercise

After a lesson on project management, students were asked to develop a project schedule for the construction of a typical single-family residence using Microsoft Project. This computer exercise followed an in-class activity where students were asked to perform similar calculations by hand. For the pneumatics lesson, students designed a mechanical arm and hand that was capable of picking items. After discussing the various methods of water treatment, students performed an experiment and used the data they collected to determine the optimum dosage of coagulant to remove suspended solids from a contaminated water sample.

7. INTEGRATING DESIGN EXPERIENCES INTO THE COURSE

As previously discussed, developing student design skills is a critical component to any first-year engineering program. As a result, several design experiences were integrated into the course.

The first design exercise was incorporated into the unit on "Engineering Design", which was within the first week of the semester. After discussing the six steps in solving a design problem—problem definition, invention, evaluation, decision, implementation, and review—the students were asked to design an aluminum foil boat to support as many pennies as possible. This exercise was relatively simple to integrate into the lesson and only required tubs of water, aluminum foil, pennies, and towels; however, it gave the students a chance to develop their design skills through brainstorming ideas and implementing their design. After each group had tested their initial design, students were given an opportunity to review their design concept and implement and test improvements to their original design. The exercise was done with teams of four students, but teams were given no instruction on how to effectively work as a team. In a later unit on teamwork, students were asked to reflect on their team's interactions during the design exercise, and how a well-functioning team might have performed more effectively.

Later in the semester, students were asked to use the design skills developed in previous lessons to complete more complex designs. After the lesson on digital logic, students performed a series of experiments to investigate the functionality of different types of simple digital gates. Once they had developed an understanding of the function and potential use of these gates, they were asked to develop a design that would perform a particular function, requiring them to apply the knowledge they had just gained.

Although several design exercises were incorporated into the course, the instructors realize that the course would benefit from additional design exercises. In future years, several of the labs that were integrated into the class will have design components added to them.

8. ASSESSING THE NEW COURSE STRUCTURE

At the completion of the course, every student in every section was asked to complete an in-class course and instructor survey. Of the 97 students enrolled in the five sections, 88 completed and returned the survey. Each question was asked using a five-point semantic differential scale with "Strongly Disagree" and "Strongly Agree" as the antonyms. The weighted mean of each question was calculated, generating a response that ranges from a worst case of 1 to a best case of 5. In response to four of the general learning objectives for the course, students responded as follows:

Table 2. Responses to General Course Assessment Questions

"I am able describe in general terms the various fields of engineering and how they relate to each other."	3.89/5.0
"I can effectively communicate results graphically and in writing."	4.10/5.0
"I can work effectively in a team."	4.16/5.0
"I can solve technical problems using an effective problem-solving strategy."	3.73/5.0

Figure 1 shows the students' responses when they were asked about their ability to explain the fundamental principles of the engineering subjects covered in the course. Nearly every one of these ratings is between 3.5 and 4.0, suggesting that the students were moderately confident of their abilities in each of these areas, but that there is room for improvement in all of them.

When asked whether they had sufficient information to make an informed decision about their major, students in the new course responded with 3.31, compared to 3.89 the previous year. This decrease is to be expected, since helping students make an informed decision was one of the most important learning objectives of the previous course and is only a secondary objective of the new course structure. When asked about the degree of difficulty of the course (with 1 being "Too Easy" and 5 being "Too Hard"), students in the new course responded with 3.10. This can be compared with the response from the previous year, which was 2.81, suggesting that students felt the new course was more difficult than the previous course.

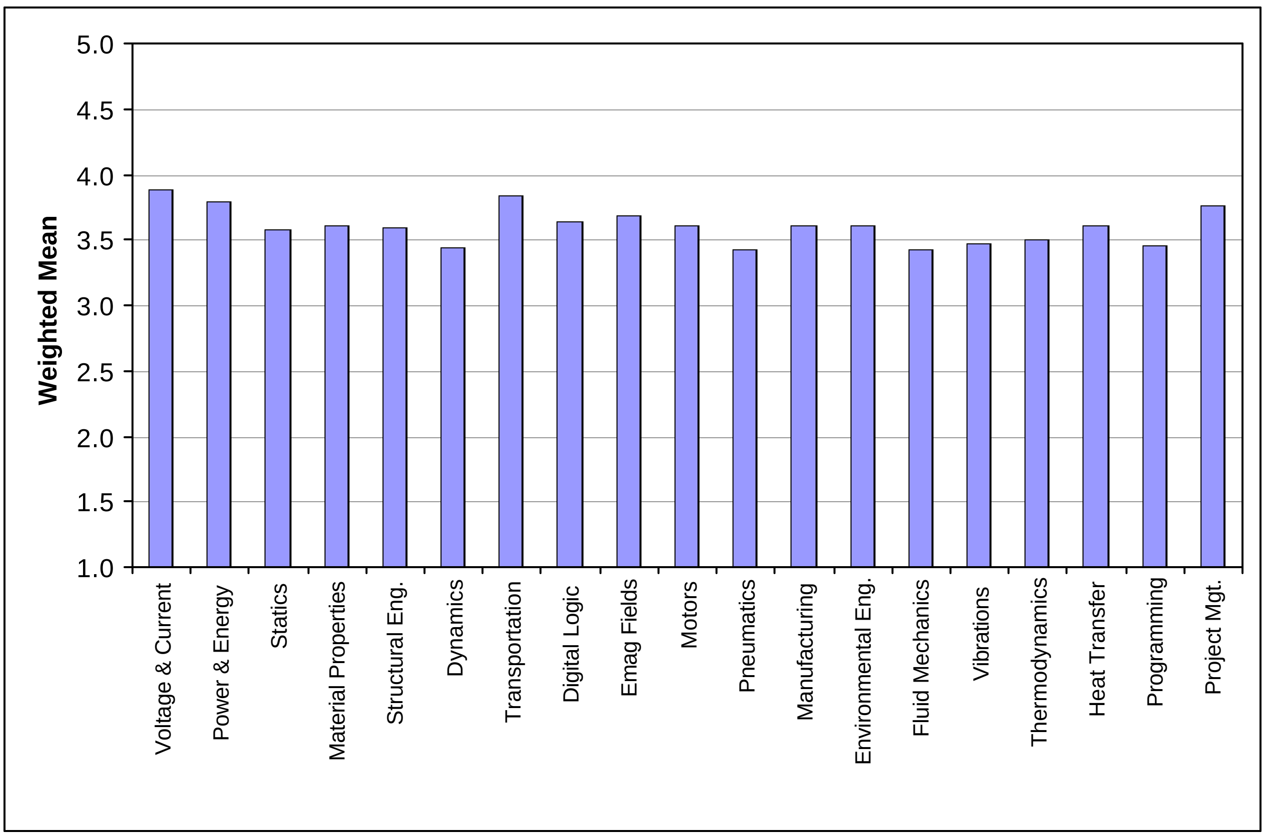

Figure 1. Self-Assessment of Technical Learning Objectives

9. LESSONS LEARNED

As previously stated, the objectives of this course were to increase the students' knowledge of the interconnections among the different engineering disciplines, help prepare them for subsequent courses in each of these fundamental disciplines, prepare them to make an informed decision about their major, and introduce topics with the appropriate level of academic rigor to effectively prepare students for the more difficult material to come in subsequent semesters. Having completed one year of the new course structure, the faculty have determined that there are several areas where opportunities for improvement exist. These opportunities exist in the overall course structure, course content, and method of presentation.

In general, students were satisfied with the overall content of the course; however, students did not always make the desired connections between topics. Of course, due to the variety of topics covered, some degree of discontinuity will inevitably exist. As a result, a careful review of the topics that were covered, and sequence of these topics will be completed prior to the second offering of the course. This should allow for a better sequencing of lessons and allow an opportunity for faculty to specifically address the connections that exist between individual topics.

Many of the topics that were covered during the first year of this course were specifically chosen to prepare students for future courses in their selected major. However, feedback from the students indicated that several of the concepts covered in various lessons were repeated in other first-year courses, such as physics. In order to address this issue, the faculty will work with other departments to minimize these overlaps. In addition, special care will be taken to make sure that where courses do overlap the material is presented in a consistent manner. In an effort to help students chose their preferred major, topics were chosen that would be representative of courses they would expect to see in the future, which inevitably resulted in an increase in the academic rigor of the course. Although there is limited data, the matriculation rate of students in this course was slightly higher than the rate that was experienced in the past. It is hoped that the decreased retention rate during the first year will result in a higher retention rate after the second semester and during the sophomore year.

There are also several areas related to method of presentation where opportunities for improvement exist. In general, the students did not like the textbook that was selected for the class. Although the textbook did cover a significant portion of the topics in the class, students did not feel as though the book added significantly to their understanding. Several options exist to address this issue. First, the faculty will consider not requiring a textbook and providing course materials they have developed themselves. Several faculty members have determined that a need exists for a textbook and are considering authoring a textbook specifically for this class.

In addition, the faculty in the course plan to work hard next year to validate the assessment results associated with this course. In particular, we will study how students' self-assessment correlates to their performance on selected exam questions, demonstrating that they are not only confident about the material, but also objectively competent in its application.

The opportunity to redesign a first-year program is both a rewarding and time intensive endeavor. The reward exists when a course is developed that will greatly enhance a student's understanding of fundamental engineering principles and sparks student interest in their chosen careers. However, these rewards do not come without significant effort and buy-in by the faculty. Although a significant number of faculty members participated in the development of the course materials, the time commitment required by the faculty teaching the course for the first time was significantly greater than anticipated. While this time commitment should decrease with future generations of the program, it is imperative that those involved with a similar process be aware of the significant time commitment required by such an undertaking.

10. CONCLUSIONS

Creating a first-year course focused on the "Fundamentals of Engineering" was a challenging task. It involved choosing the most important concepts, extracting topics from these concepts that could be taught in a two-hour class period, and finding effective learning exercises for these concepts. By using a variety of classroom and laboratory exercises, the faculty members involved feel the course was reasonably successful. We were able to increase the technical content and the depth of the material while still maintaining a degree of difficulty appropriate for a first-semester student. Of course, as with every new project, we have many ideas for improvements to be made in time for next year's course, and we look forward to teaching it again.

REFERENCES

S. A. Brandt, C. A. Fisher, D. S. Hansen, S. T. Kuennen, and P. J. Neal, "Get 'Em While They're Young! Integrated Engineering for Freshmen," *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition* (2004).

G. D. Catalano, "The Freshman Engineering Program at the State University of New York at Binghamton," *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition* (2004).

J. B. Connor, J. C. Malzahn-Kampe,"First Year Engineering at a Virginia Polytechnic Institute and State University: A Changing Approach,"*Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition* (2002).

N. Craig, M. Maher, and W. Peters, "Recipe for Complexity: A Freshman Learning Experience," *Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition* (2003).

H. Diefes-Dux, D. Follman, P.K. Imbrie, J. Zawojewski, B. Capobianco, and M. Hjalmarson, "Model Eliciting Activities: An In-class Approach to Improving Interest and Persistence of Women in Engineering," *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition* (2004).

H. A. Diefes-Dux, P.K. Imbrie, and T. Moore, "First-Year Engineering Themed Seminar: A Mechanism for Conveying the Interdisciplinary Nature of Engineering," *Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition* (2005).

J. E. Froyd and M.W. Ohland, "Integrated Engineering Curricula," *Journal of Engineering Education*, **94**, pp. 147-164 (2005).

J. F. Gardner, H. D. Ackler, A. J. Paris, and A. J. Moll, "Rethinking First Year Engineering at Boise State: Assessment and Improvement," *Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition* (2002).

P. Hirsch, J. Anderson, J.E. Colgate, J. Lake, B. Shwom, and C. Yarnoff, "Enriching Freshman Design Through Collaboration with Professional Designers," *Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition* (2002).

L. Katehi, K. Banks, H. A. Diefes-Dux, D. K. Follman, J. Gaunt, K. Haghighi, P. K. Imbrie, L. H. Jamieson, R. E. Montgomery, W. C. Oakes, and P. Wankat, "Preeminence in First-Year Engineering Programs," *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition* (2004).

P. Larochelle, J. Engblom, and H. Gutierrez, "A Cornerstone Freshman Engineering Design Experience," *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition* (2004).

W. K. LeBold, H. Diefes, W. C. Oakes, "Helping First Year Students Make Critical Career Decisions," *Proceedings of the 1999 American Society for Engineering Education Annual Conference & Exposition* (1999).

R. Leland, J. Richardson, T. Lee, and J. Dantzler, "Teaching Freshman Engineering Students to Solve Hard Problems," *Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition* (2005).

H. M. Pierson and D. H. Suchora, "The Rube Goldberg Three-Minute Timer: A Design Based Learning Tool For Engineering Freshman," *Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition* (2002).

H. M. Pierson and D. H. Suchora, "First Year Engineering Curriculum at Youngstown State University," *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition* (2004).

D. Pines, M. Nowak, H. Alnajjar, L. I. Gould, and D. Bernardete, "Integrating Science and Math into the Freshman Engineering Design Course,"*Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition* (2002).

H. K. Qammar, H. M. Cheung, E. A. Evans, S. Prettyman-Spickard, F. S. Broadway, and R. D. Ramsier, "Impact of Vertically Integrated Team Design Projects on First Year Engineering Students," *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition* (2004).

K. F. Reardon, "A Project-Oriented Introduction to Engineering Course," *Proceedings of the 1999 American Society for Engineering Education Annual Conference & Exposition* (1999).

C. J. Rowe, A. Mahadevan-Jansen, "Module-based Freshman Engineering Course Development" *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition* (2004).

T. Rutaw and G. Mason, "A Learning Community of University Freshman Design, Freshman Graphics, and High School Technology Students: Description, Projects, and Assessment," *Journal of Engineering Education*, **94**, pp. 245-254 (2005).

M. Vigeant, J. W. Baish, D. Cavanagh, R. J. Kozick, S. Petrescu, R. Zaccone, and R. D. Ziemian, "Introducing First-Year Students To Engineering, Economics, and Social Responsibility: ADA Compliance as a First Project," *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition* (2004).

R. Whalen, S. F. Freeman, B. K. Jaeger, and B. Maheswaran, "Teamwork is Academic: The Gateway Approach to Teaching Engineering Freshmen," *Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition* (2005).