Implementing a Common First Year Engineering Program at Michigan Tech

Sheryl A. Sorby, Amy E. Monte, Gretchen L. Hein
Engineering Fundamentals
Michigan Technological University
Houghton, Michigan

Abstract

In the fall of 2000, Michigan Tech made a calendar conversion from quarters to semesters and, in conjunction with this, simultaneously overhauled the engineering curricula. One of the changes that we adopted was the development of a common first year engineering program. Prior to the calendar conversion, each academic department in the College of Engineering established its own curriculum for the entire four-year degree program. During the course of the curricular revamping, we also received funding from the NSF under the Action Agenda program with a portion of the grant dedicated to the implementation of the common first year engineering program. In designing our first year program, we “borrowed” ideas from several engineering schools, primarily those universities involved in the various NSF coalitions. This paper describes the procedure we followed to implement this sweeping curricular change and highlights the features that we incorporated into our first-year engineering program. Preliminary feedback and assessment from the first-year program as well as “lessons learned” will also be presented in the paper.

The Timeline and Procedure for Change

Step 1: Establishing the Leadership. In December of 1996, a new Dean of Engineering was hired at Michigan Tech. Soon after arriving on campus, he met with one of the authors (Sorby) to discuss his desire to develop a common first-year engineering program. Shortly thereafter, the decision was made to convert from quarters to semesters at Michigan Tech. The initiative to change the academic calendar to semesters was faculty driven, based primarily on educational objectives, and was not imposed by the administration or state government. In our quarter calendar, the winter term was disjointed with several breaks during its 10-week duration. The sentiment among the faculty was that this disjointed calendar along with the fast pace of 10-week quarters in the fall and spring did not allow students enough time for reflection on the material they were learning. There was a commitment on the part of the faculty and administration in the College of Engineering (COE) to look critically at existing programs and develop new, innovative curricula rather than “cut and paste” our quarter courses to fit the new academic calendar. In the coming months, the dean appointed Sorby to be the Director of General Engineering, charged with developing and implementing a common first-year engineering program at Michigan Tech. At about the same time, a new Associate Dean of Engineering for Academic Programs was named (Dr. Mark Plichta) and charged with leading the curriculum reform efforts in the college through the conversion to semesters.

Step 2: Testing the Waters. In the fall of 1997, at the annual engineering chairs retreat, a common first-year program was discussed and endorsed by the chairs with the understanding that this change would be implemented in the fall of 2000 with the conversion to semesters. Chairs supported this program for two primary reasons: 1) students would have a degree of flexibility in switching from one major without loss of credits or time, and 2) students would get a "taste" of engineering in their first year at Michigan Tech. Further discussions throughout the 1997-98 academic year focused on the content of the program. During the spring term of 1998, meetings between Sorby, the deans, and the curriculum committees of each department in the college were conducted to gather input regarding the desired characteristics of the first-year engineering program. At about this same time, Plichta and Sorby teamed to write a successful grant proposal under the NSF Action Agenda program with a portion of the grant dedicated to the implementation of the first year engineering program.

Step 3: Developing the Plan. During the summer of 1998 a committee was formed, chaired by Sorby, to develop the implementation plan for the first-year engineering program and volunteers from the various departments were sought. The planning committee sent a survey to all engineering faculty where they were presented with a list of 15 potential topics for inclusion in the first year engineering courses and were given 50 points to "spend" on them. In this way, they could assign more points in the categories that they deemed were important and fewer points in categories that they deemed unimportant. About 34% of the surveys were returned with the responses compiled and presented in Table 1.

Table 1: Survey Results of Topical Content for First Year Courses

Topic	Points
Oral and Written Communication	327
Basic Computer skills (applications)	296
Graphics/Visualization	242
Problem Solving Strategies	220
Engineering Careers/Disciplines	188
Design Process and Project	177
Computer Programming	145
Data Collection and Analysis	137
Computer Aided Drafting (2D)	135
Teaming	121
Engineering Ethics	120

Table 1: Survey Results of Topical Content for First Year Courses

Topic	Points
Computer Aided Design (3D)	113
College Survival Skills	107
Reverse Engineering/Mechanical Dissection	107
Environmental Issues	71

Using the results from this survey, the committee membership developed an implementation plan and a final report. This report was distributed to the faculty in the COE and meetings were set up between Sorby, the deans, and the faculty to discuss the proposal with each of the departments in the college. In December of 1998 the faculty in the COE voted on the proposal and the end result was a program with significant support by the engineering faculty. Five of the eight departments in the college were nearly unanimous in their support of the program, one department approved it by a 20-10 vote, one department was virtually evenly split, and only one department voted 5-10 opposing the program. The department that opposed the plan (Chemical Engineering), did so primarily because the faculty sentiment was that there was not enough chemistry in the program--only one semester required. The faculty in the two departments that did not unanimously support the program cited “loss of control” as their primary reason for not supporting the common first year.

Step 4: Refining the Plan. Shortly after the positive vote by the engineering faculty, a First Year Oversight Committee was established by the dean with one faculty member from each department in the COE invited to serve. The committee was charged with 1) resolving remaining issues that had arisen during departmental meetings regarding the program, 2) making decisions regarding software packages to be utilized in the program, 3) approving final outlines for the first year courses, and 4) developing an assessment plan for the first-year engineering courses. The departmental representative on this committee generally was not the same person as that of the planning committee. The oversight committee met over the next several months to finalize plans for the program and further refine the implementation plan established by the planning committee.

Step 5: Implementing the Plan. The decision was made to utilize active, collaborative learning and to integrate the use of technology tools in the engineering classes wherever feasible. For this reason, the need for a new type of classroom would be required to successfully implement this program. Three classrooms were identified during the summer of 1998 and plans were made and implemented for their renovation. The final room design included cloverleaf-shaped tables that could accommodate a team of four students with one computer per “leaf” (a total of 16 students and 4 computers per table). Figure 1 shows before and after pictures of the classrooms that were renovated in support of the first year engineering program.

Unfortunately, our colleagues in the math and physics departments have not yet been willing to fully implement active, collaborative learning in their respective classrooms. However, some changes have been instituted in our first year calculus courses. Our first year calculus courses stress teamwork and collaborative assignments, however, lectures are still the primary mode of

Before After

Figure 1. First Year Engineering Classrooms

instructional delivery in these courses. We hope the success of the students in the first year engineering program will illustrate to these departments that students do perform and learn better in an active environment.

During the 1999-00 academic year, several aspects of the program were pilot-tested in various classes. Since the first year engineering classes did not really exist in their final form, it was impossible to fully test all of our implementation ideas at that time. Two key pilot tests were conducted in support of the program: 1) the integration of topics from math, physics, and engineering, and 2) the development and delivery of engineering explorations by the various departments in the COE. Results from these pilot tests were encouraging and plans were developed for the full-scale implementation of these program features over the coming months.

Due to the wide variety of software packages to be used in the program and the large number of students to be served by these courses, having the first year engineering courses taught by “volunteer” faculty from the COE was not considered to be a viable option for Michigan Tech. The decision was made to staff these courses with a dedicated cadre of faculty and several new faculty were hired to help teach in the program during the spring of 2000. Training sessions were held for the new faculty during a summer orientation program two weeks before classes began in the fall of 2000.

The software packages selected for use in the first year engineering program were ones commonly used in the engineering departments on campus and in industry. For instance, upper division mechanical, biomedical, electrical and computer engineering students use Matlab in several courses. Therefore, this package was selected for the first year courses as a tool for students to learn about computer programming. MathCAD was selected to illustrate how equation solvers are used as engineering tools because materials, civil and environmental engineering students use this package as an analysis tool in their junior and senior level classes.

On August 28, 2000 the full-scale implementation of our first year engineering program finally began after nearly four years of discussion, planning, and testing.

The Michigan Tech First Year Program

The curriculum template for the first year program at Michigan Tech is presented in Figure 2. Engineering classes meet for three 1.5-hour sessions per week (2 credits lecture, 1 credit lab).

First Semester	Cr
Chemistry I	4
Calculus I	4-5
Engineering I	3
General Education	3
Physics Lab I	1

Second Semester	Cr
Physics I	3
Calculus II	4
Engineering II	3
General Education	4
One Course by Major	1-4

Figure 2. Curriculum Template for First Year Program

Students who are not calculus ready are not able to start in the first year engineering courses in the fall semester, but are required to make up their deficiency before proceeding through the curriculum. The recommended first semester for these students is presented in Figure 3. The one-credit engineering seminar is a pass/fail course that focuses on study skills, time management, wellness, and other topics for the successful transition to university life.

First Semester	Cr
Pre-Calc	4
Pre-Chem or Chemistry I	3-4
Two General Education Courses	6
Engineering Seminar	1-P/F

Figure 3. First Semester Curriculum Template for Students not Calc-Ready

Features of the Michigan Tech First Year Program

Integration of Math, Science, and Engineering. It is our intent that the first year Math, Science and Engineering (MSE) courses will be integrated wherever feasible. Examples of the type of integration that are possible include: manipulating and graphing data from Chemistry lab using computer tools in the engineering course, applying derivatives and integrals learned in math to “engineering” problems, learning an introduction to statics and dynamics in the engineering course as they are learning about forces and motion in Physics. In our first offering of the engineering courses, the integration of these topics was minimal at best, however, we are currently working to address this problem.

During the 2000-2001 academic year, the integration of math, science and engineering occurred only within the engineering courses. Math and science instructors are encouraged to include engi-

Proceedings of the 2001 American Society for Engineering Education Annual Conference and Exposition

neering examples in their lectures (and some do), however, meaningful integration has not yet been fully achieved. One way to encourage more integration between subjects is to establish good communication between the math, science and engineering instructors. In the pilot studies, we found that students who had trouble in one course were have problems in others. Good communication between the departments would allow us to help students more rapidly.

Cohort Scheduling. Since the intent is that the MSE courses will be integrated in the first year, cohorts of students will sign up for these classes as a "block." Therefore, students in a cohort will have the same schedule for these classes. The cohort size is generally either 20 or 24 students depending on classroom and faculty resources. Physics and Chemistry labs consist of one cohort of students while Calculus and Physics recitations consist of two cohorts. Engineering classes consist of either two or three cohorts depending on classroom availability. Chemistry and Physics lectures typically consist of around 10 cohorts of students. By utilizing cohort scheduling, we believe that learning communities will be established and that better integration of subject matter is possible. Non-cohorted sections of the MSE courses are also offered as necessary to accommodate transfer students, students with advance placement credit, students who fail one or more of their MSE courses, or students who get out of sequence for some other reason.

Active Collaborative Learning. In order to achieve better student understanding and retention of material, we have adopted an active, collaborative teaching style throughout the first year engineering courses. By this method, we spend approximately one-third of each session lecturing on the topic for the day. Students then work either individually or in teams to solve problems or to "discover" the answers to questions posed by the instructor. During the time that students are actively working, the instructor and an assistant circulate through the classroom, answering questions as needed. We also spend a portion of class time talking about teaming with several team projects and team homework assignments given out during the semester.

Technology in the Classroom. Prior to the implementation of our first year program, most instruction in the use of computer tools within the engineering curricula was relegated to a few "computer-intensive" courses with separate computer labs staffed by TAs. In this way, most engineering students did not develop a full appreciation of the computer as a problem-solving tool until well into their junior or senior year (if ever). In our first year engineering courses, the computer is utilized as a regular part of the problem-solving process. We hope that the integration of technology in the classroom will enable our students in future years to become more adept at utilizing software tools in the solution of a wide variety of engineering problems throughout their college careers and beyond.

Engineering Explorations. As a part of their course work, students in the first of the two engineering courses are required to participate in a minimum of four hands-on activities from at least three disciplines outside of class time. These activities have been designed to expose them to the engineering majors and are 2-3 hours in duration. Every semester, each engineering discipline (mechanical, electrical, computer, civil, environmental, materials, biomedical and mining) develops a schedule for when their labs/rooms are available to conduct these activities and staff them with either graduate students, non-academic staff or faculty as they deem appropriate. Students in the first engineering course sign up for four of these activities through the semester over the web. Sample titles of the engineering explorations include: 1) Concrete: Sexier Than You Think, 2) Are

Some Civil Engineers All Wet?, 3) Material and Manufacturing Choices in Bike Frame Construction, and 4) Geological Engineering of Water Wells. At the conclusion of the explorations, 79% of the first year engineering students reported that they were prepared to select an engineering major.

Assessment Plan and Preliminary Feedback

Working through our first year oversight committee, goals and objectives as well as an assessment plan for the first year engineering program were developed as outlined in Table 2.

Table 2: First Year Engineering Program Goals and Assessment Measures

Goals--Students will:	Assessment Measures
Develop an appreciation for the engineering profession	Pittsburgh Freshman Engineering Survey (pre- and post-surveys)
Develop proficiency in the use of modern software tools in solving engineering problems and in engineering design	Computer Lab Practicals
Be able to synthesize mathematical and scientific principles in solving basic engineering problems	Differential Aptitude Test: Mechanical Reasoning, (pre- and post-testing)
Improve communication (written, oral and graphical) and visualization skills, especially regarding technical communication	Mental Cutting Test, Writing Samples (pre- and post-testing)
Understand ethics and its importance to the engineering profession	Ethics exam questions
Understand the design process through a practical, hands-on design experience	Design project evaluation

To determine the successfulness of the first year engineering courses, an extensive assessment plan has been developed. Over the course of the year, students' pre-skills and post-skills are being evaluated. This evaluation is accomplished through surveys, computer lab practicals, assessment tests, and evaluation of written and oral communication (See Table 2).

Surveys. The Pittsburgh Freshman Engineering Survey is being administered at the beginning and end of the first year. Comparisons between responses in the pre-questionnaire versus the post-questionnaire will be used to determine the self-reported "value added" from the first year engineering program. To date, students have completed the pre-questionnaire.

Students are being surveyed regarding Engineering Explorations. These surveys are still being analyzed. Preliminary results show that 53% of the students responding think three or four explorations is a reasonable requirement. Of the students responding 33% appreciate the opportunity to learn more about engineering majors even though they already have chosen a major. And, as stated previously, 79% indicate that they feel prepared to select an engineering major.

A “Focus Group” of ten students met with a representative from the oversight committee and the Associate Dean for Academic Programs at the end of their first semester in the program. This meeting allowed students to have input to the improvement of the first year experience through their opinions and suggestions. The following is a list of aspects the students reported finding beneficial in the first semester engineering course: computer use, teaming, interdisciplinary opportunities, design project, and the “concept” of explorations. The students found the following aspects least beneficial: lack of common team schedules, rushed delivery of topics, and lack of flow and continuity in course topics. These comments are currently being compiled and will be used to help improve future offerings of the class.

Computer Lab Practicals. Two lab practicals are being administered: one at the end of the first semester and the other at the end of the second semester. The first practical assesses individual student computer skills using a spreadsheet. The second practical assesses individual student computer skills using a computer tool of their choice. Detailed results from the first lab practical are still being evaluated. A preliminary sample of 190 students indicates a mean of 79% with a standard deviation of 17%.

Assessment Tests. Several tests will be administered to determine progress towards meeting course goals. The Differential Aptitude Test: Mechanical Reasoning will be administered at the beginning and end of the first year. On this test, students are asked questions regarding “how things work.” Students scores and gain scores will be analyzed to determine improvements in mechanical reasoning ability. The Mental Cutting Test is being administered at the beginning and end of the second semester. In the mental cutting test, a plane is passed through an object and students must select the “correct” view of the new section. This will be used to determine gains in spatial visualization skills. Understanding of engineering ethics will also be evaluated using questions from a first semester exam.

Ethics Understanding Assessment. In the first engineering course, nine questions on an exam were dedicated to engineering ethics and academic integrity. The engineering ethics questions were taken from the Dilbert Game (an “Ethics Challenge” game developed by Lockheed Martin) which students played during class. Overall, the students were able to recognize if an action was ethical--95% of the students answered the engineering ethics questions correctly. The academic integrity question responses were surprising. In general, students recognized when they should not use another person’s work and that they were violating the academic integrity policy when they let someone use their work; 92% of the students answered these three questions correctly. The students did have trouble with the sharing of computer files and passwords. For example, only 61% of the students responded that sharing their computer account password was unethical.

Communication Skills. Writing samples are being collected at the beginning and end of the first year, for a randomly selected group of students. These samples will be compared to determine the “value added” regarding written communication skills. In addition, students are giving presentations during the first and second semesters. Comparisons between student performance on these presentations will be used to determine improvements in oral communication skills.

Assessment of Design. Samples of design project reports and presentation assessments were collected after the first engineering course. These will be compared to samples collected at the end of the second engineering course and will be independently evaluated by our oversight committee.

Conclusions

Over the course of the last four years, Michigan Tech has been in the process of overhauling the engineering curricula. One of the changes that we adopted is the development of a common first year engineering program. Students in this program are taking Calculus, Engineering, Chemistry, Physics, and general education courses. Some of the key aspects of this program include: integration of math, science, and engineering; cohort scheduling; active collaborative learning; technology in the classroom; and engineering explorations. Program assessment will be conducted to determine how successful the first year engineering program is. Our assessment plan includes: student surveys, computer lab practicals, standardized assessment tests, and written and oral communication. Preliminary findings indicate that students find the following aspects of our program beneficial: computer use, teaming, interdisciplinary opportunities, design project, and the explorations. Findings from these assessment tools will help improve the first year engineering program at Michigan Tech in the future.

Acknowledgement

The authors would like to gratefully acknowledge the National Science Foundation for their support of this work through grant No. EEC-9872533. We would also like to thank The GE Fund for financial support of one of the pilot studies associated with this project and Ford Motor Co., Caterpillar, Inc., and the Dean’s office for financial support of classroom renovations.

SHERYL A. SORBY

Sheryl A. Sorby is an Associate Professor of Civil and Environmental Engineering and Chair of the Engineering Fundamentals Department at Michigan Technological University. Sorby is active in the American Society for Engineering Education and the American Society of Civil Engineers where she currently serves as chair of the Committee for Faculty Development. She is a recipient of the Dow Outstanding New Faculty award and the Distinguished Teaching award, both from the North Midwest Section of ASEE.

AMY E. MONTE

Amy E. Monte is a lecturer in the Department of Engineering Fundamentals at Michigan Technological University. She received her BS and MS in Environmental Engineering at Michigan Technological University. Monte teaches Fundamentals of Engineering I and II, and Foundations for Success. She also has and is developing and delivering prepatory engineering math courses.

GRETCHEN L. HEIN

Gretchen L. Hein is a lecturer in the Department of Engineering Fundamentals at Michigan Technological University. She received her BSME at Kettering University in Flint, MI and her BSE at Purdue University in West Lafayette, IN. Prior to pursuing her masters degree, she worked as a mechanical engineer at General Motors Corporation. She received her Ph.D. from Michigan Technological University. Hein teaches Fundamentals of Engineering I and II, and Foundations for Success.