# Mathematics and Engineering: Working Together to Satisfy ABET's EC2000

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Abstract

On November 1, 2001, the Accreditation Board for Engineering and Technology (ABET) awarded Carroll College the ABET Innovation Award. This award, which has not been conferred since 1991, was given to Carroll College because of the cross-disciplinary support of the new ABET accreditation standards (called Engineering Criteria 2000), both in Carroll's mathematics and engineering programs. The mathematics curriculum at Carroll supports satisfaction of the ABET criteria, while at the same time, engineering applications enrich the study of mathematics, not only for engineering majors, but also for mathematics, mathematics education, science, and computer science majors. Interdisciplinary student team projects, written reports and oral presentations, and the extensive use of computing and information technologies are all part and parcel of Carroll's mathematics curriculum. These features support EC2000 beyond the basic requirement for a sequence of courses to satisfy the mathematics content requirements of the engineering program. In particular, the mathematics curriculum plays a key role in supporting satisfaction of Criterion 3, outcomes a-k.

## Introduction

Carroll College, founded in 1909, is a 4-year Catholic liberal arts college in Helena, Montana. Reflecting our motto, *Not for School, but for Life*, the college emphasizes preparation of its students for professional careers, as well as their exposure to the liberal arts and sciences. Because Carroll is a small college with approximately 1400 students, the Department of Mathematics, Engineering, and Computer Science includes the programs, faculty, and students in all three of the academic areas designated by the department's title. In line with its mission, Carroll College in 1996 began offering a new 4-year program leading to a Bachelor of Arts degree with a major in civil engineering. In the fall of 2000, after graduating our first class with this degree, we applied to ABET (the Accreditation Board for Engineering and Technology) for accreditation of our new civil engineering program. Not only was our program accredited, but in November 2001, Carroll College was also given the ABET Innovation Award, which has not been conferred since 1991. The citation on the award reads as follows:

> "... for Adoption of Student Goals for mathematics majors that embrace the principles of ABET's Engineering Criteria 2000 and for development of an innovative, cross-disciplinary curriculum tailored to the needs of mathematics and other disciplines."

The Mathematics Connection

In 1992, the Carroll College Department of Mathematics, Engineering, and Computer Science, recognizing the dramatic impact that technology was having on the world of applied mathematics, began a major effort to formulate a new and innovative mathematics curriculum. This new mathematics curriculum is designed to engage students in the art of mathematics while at the same time focusing on a wide array of interesting, real-world applications. This effort has resulted in changes in both what is taught in our mathematics classrooms and how it is taught.

One of the keys to the success of our curriculum project has been Carroll's membership in the Project InterMath Coalition of Colleges and Universities. The coalition is led by the U. S. Military Academy at West Point and other members include Harvey Mudd College and Macalaster College. Project InterMath has been funded by the National Science Foundation, Division of Undergraduate Education. Through Project InterMath, mathematics faculty members interact with faculty members in other disciplines, including engineering. Together, they develop cross-disciplinary applied mathematics projects for undergraduates and formulate mathematics curricula that are tailored to the needs of other disciplines. One of the goals of Project InterMath is to engage in curricular and cultural reform through the development and use of student projects that integrate topics from mathematics with those from partner disciplines including engineering and science. In addition to developing and using such student projects (called Interdisciplinary Lively Applications Projects or ILAPS), we have also designed and implemented a new and innovative mathematics curriculum. The features of this curriculum include: 1) an integration of mathematical topics especially in the first two years, 2) a focus on mathematical applications from a wide variety of disciplines, 3) extensive use of computing and information technology, and 4) an emphasis on cooperative student work to do projects, write reports, and give oral presentations. These features played a key role in helping us satisfy ABET's Engineering Criteria 2000 to obtain accreditation for a new major in civil engineering.

The first two years of our mathematics program, which is required for all engineering and mathematics majors, has been restructured and consists of four courses. In these courses we have integrated calculus with discrete dynamical systems, linear algebra, differential equations, probability and statistics, and the use of calculator and computer technology. Interdisciplinary Lively Application Projects (ILAPs), where students work in small groups on real-world applications of mathematics, are now a fundamental component of this two-year curriculum. ILAPs make the integration of mathematical topics more natural, and they usually require the use of computing and information technologies. Many of the ILAP topics are taken from engineering. This engages engineering students in applications that are relevant to their major even in their early mathematics courses. ILAPs also provide a vehicle for students to give written and oral presentations. Since our courses require student interaction and group work, they are not taught solely in a lecture format.

The Engineering Connection

In 1992, the Department of Mathematics, Engineering, and Computer Science also initiated the plan to offer a new major program in civil engineering. This new program enrolled its first students in the fall of 1996, and graduated its first class in the spring of 2000. In August of 2001,

ABET accredited our civil engineering program, retroactive for the first graduating class of 2000.

For more than 30 years, Carroll has had a 3-2 engineering program in affiliation with 7 engineering schools: Columbia University, the University of Southern California, the University of Notre Dame, Gonzaga University, the University of Minnesota, Montana State University, and Montana Tech. In addition, many of our mathematics majors have pursued graduate study in engineering at a variety of schools, including Columbia University, the University of Notre Dame, Stanford University, Virginia Tech, the University of Oklahoma, the University of Washington, Washington State University, and Montana State University.

It was, in part, on the basis of the successes of our students pursuing degrees in engineering that we decided to institute a 4-year program leading to a Bachelor of Arts degree with a major in civil engineering. We knew from the start that the mathematics program would play a key role in supporting the engineering program. This became more evident when ABET released its new Engineering Criteria 2000.

## Design of the Mathematics Curriculum

As we began our curriculum development project in the early 1990's, we adopted the following goals:

1. To create an integrated and interdisciplinary curriculum that is applications oriented and makes extensive use of calculator, computer, and information technology.

2. To make the curriculum appealing to students so that it fosters excitement for learning, enables students to apply mathematics, and develops skills for the workplace by promoting teamwork and oral and written presentations.

In presenting mathematics as a unified topic, we strive to preserve the beauty and integrity of the subject, while focusing on the solution of meaningful applications. We have experienced considerable success in achieving the stated goals, but more work remains to be done. Our plan encompasses all courses taught in the mathematics department, but the following paragraphs refer specifically to the first two-year sequence of mathematics courses that is required for all of our engineering and mathematics majors.

## First Two Years of Mathematics for Mathematics and Engineering Students

The first two years of our program in mathematics, required for our mathematics majors and for our engineers, has been restructured and consists of four courses, the first two being 4 credits each and the second two 5 credits each. The first two courses are also required for computer science and chemistry majors. In these courses, we have integrated calculus with discrete dynamical systems, linear algebra, differential equations, probability and statistics, and the use of calculator and computer technology. The incorporation of Interdisciplinary Lively Application Projects (ILAPs), where students work in small groups, is now a fundamental component of this

two-year curriculum and these projects have helped greatly in making the integration of mathematical topics very natural. They also provide a vehicle for students to give written and oral presentations. Our mathematics classes promote student interaction and group work.

These courses require the use of a graphing calculator with computer algebra system (CAS) capabilities, and we have a formal computer lab session in each course each week. We use spreadsheets, MATLAB, and SPSS at times, but the primary software used in the course sequence is *Mathematica*. Examples of the types of modules we have written for our computer labs can be found on the CD that accompanies the 10th edition of *Thomas' Calculus*, © 2001, Addison-Wesley-Longman (AWL) or at the AWL website at http://www.awl.com/thomas. The authors, together with Brigadier General Chris Arney of the US Military Academy at West Point, wrote 38 technology modules to accompany the calculus text in both of its versions. The modules are available in either *Mathematica* or Maple and reflect, in part, the interdisciplinary and integrated nature of our curriculum. We use other lab modules, which are not included with the book, that encompass other mathematical topics. These additional modules focus on difference and differential equations, linear algebra, and probability and statistics.
Having been part of our curriculum for each of the past six years, these integrated courses are fairly well developed; however, refinements are made each year. In addition to the ILAPs that we already use, we are exploring ways to include carry-through ILAPs and projects that have an engineering design component. In our attempts at integrating topics, we still have work to do. Specifically, we would like to integrate probability and statistics in a more formal way into the first year, instead of teaching it primarily during the latter part of the second year. Since we use the calculator and computer extensively, we incorporate programming into each of our courses, but we have not been able to weave a formal programming component through both years.

Textbooks currently being used for the first three courses are *Thomas' Calculus*, 10th edition, by Finney, Weir, and Giordano, Addison-Wesley-Longman, © 2001 and *Discrete Dynamical Systems*, by Arney, Giordano, Robertson, McGraw-Hill, © 2000. Texts used in the fourth course are *Differential Equations and Linear Algebra*, 2nd edition, by Goode, Prentice Hall, © 2000 and *Modern Engineering Statistics*, by Lapin, Duxbury, © 1997.

For each of these four courses we have delineated the number of credits apportioned to each mathematical topic area. They are as follows:

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|---|---|---|
| Mathematics 1 (4 credits): | Differential Equations | 1 credit |
| | Calculus | 3 credits |
| Mathematics 2 (4 credits): | Linear Algebra | 1 credit |
| | Calculus and Differential Equations | 3 credits |
| Mathematics 3 (5 credits): | Multivariable Calculus | 4 credits |
| | Linear Algebra | 1 credit |
| Mathematics 4 (5 credits): | Linear Algebra | 1 credit |
| | Differential Equations | 2 credits |
| | Probability and Statistics | 2 credits |

It should be noted that this program in every way meets the criteria set forth in the National Council of Teachers of Mathematics (NCTM) Standards for preparation of secondary mathematics teachers, and our first-year course is currently being taught for college credit at three local high schools.

The Mathematics Curriculum Supports Satisfaction of EC2000

The Carroll College Department of Mathematics, Engineering, and Computer Science has focused on ways in which our mathematics program supports satisfaction of the ABET Engineering Criteria 2000, Criterion 3, Program Outcomes a-k. The table on the page that follows shows how our two-year mathematics program addresses the ABET Engineering Criteria 2000 regarding Program Outcomes and Assessment.

| **ABET Engineering Criteria 2000:** ***Criterion 3. Program Outcomes and Assessment*** | |
|---|---|
| **Engineering programs must demonstrate that their graduates have:** | **Carroll's two-year math sequence** |
| (a) an ability to apply knowledge | Uses calculus, linear algebra, difference and differential equations, and probability and statistics to solve practical problems |
| (b) an ability to design and conduct experiments, as well as to analyze and interpret results | Develops math modeling skills<br>Introduces statistical analysis of data<br>Validates results produced by computer software |
| (c) an ability to design a system, component, or process to meet desired needs | Addresses reliability of systems |
| (d) an ability to function on multi-disciplinary teams | Incorporates mini-projects and ILAPs (Interdisciplinary Lively Application Projects)<br>Focuses on group projects and presentations |
| (e) an ability to identify, formulate, and solve engineering problems | Develops math modeling skills |
| (f) an understanding of professional and ethical responsibility | Focuses on team participation as well as individual responsibility |
| (g) an ability to communicate effectively | Develops writing and speaking skills<br>Develops technical communication skills |
| (h) the broad education necessary to understand the impact of engineering solutions in a global and societal context | Addresses ethical, social and/or aesthetic issues associated with topics in projects |
| (i) a recognition of the need for, and an ability to engage in life-long learning | Focuses on being open to a variety of approaches in solving problems and being open to new ideas and new technologies |
| (j) a knowledge of contemporary issues | Promotes web research on math-related contemporary issues |
| (k) an ability to use techniques, skills, and modern engineering tools necessary for engineering practice | Utilizes computers extensively, for computation, visualization, programming, and presentation<br>Introduces web research |

## Biographical Information

JOHN L. SCHARF
Professor Scharf is Chair of the Department of Mathematics, Engineering, and Computer Science and holds a Ph.D. in civil engineering from the University of Notre Dame. Since he began teaching at Carroll in 1976, he has taught a wide variety of courses at Carroll College in mathematics, engineering, physics, and computer science. In the fall semester of 2001, he was a visiting professor of mathematics at the US Military Academy at West Point.

MARIE M. VANISKO
Professor Vanisko is Director of the Mathematics Program in the Department of Mathematics, Engineering, and Computer Science and holds an M.A. degree in mathematics from the University of Montana. She has directed Project InterMath at Carroll and is primarily responsible for development of the current mathematics curriculum. In the spring semester of 2002, she was a visiting professor of mathematics at the US Military Academy at West Point.