Reforming Technical Mathematics: A Collaborative Effort

Robert L Kimball
Wake Technical Community College

Abstract

The National Council of Teachers of Mathematics (NCTM), the American Mathematical Association of Two-Year Colleges (AMATYC) and the Mathematics Association of America (MAA) have called for changes in the content and methodology of mathematics education. Industry is also calling for changes—changes in the product. Industry want graduates who can think critically, communicate effectively, and solve problems using a variety of tools. This paper discusses the experiences of the author as faculty in his department have begun to implement standards-based changes to curriculum and changes in pedagogy designed to produce students who can be successful whether they decide to enter industry or to continue their education. Included is information about three National Science Foundation grants that have provided support for the process.

1. Introduction

Wake Technical Community College (WakeTCC) is a fairly large (8000 FTE) two-year college in Raleigh, NC. The math faculty has worked closely with people in industry and with faculty in the engineering technology division to provide mathematics and physics courses to meet the needs of students.

2. The Need for Change

"We never had that." You've probably heard this phrase from students as you attempted to get them to apply a mathematical topic in an unfamiliar application. We heard the phrase in physics classes; however, the instructor was sometimes the same instructor who had taught them the math only a semester or two before. As mathematics faculty talked with technology instructors, we found that indeed there was a disconnect between the mathematics courses and the applied courses. Students were having trouble applying mathematical concepts learned independently of applications. Many mathematics texts are written with material grouped into chapters that are related somehow mathematically. For example, a chapter on quadratic functions might include: Completing the Square, the Quadratic Formula, Equations in Quadratic Form, Graphs of Quadratics, and then some Applications of Quadratics. The book would then move to another chapter, perhaps on Logarithmic Functions, with the student never seeing the connections between the two types of functions. And, more importantly, the student never had to solve applications, which require the student to select the appropriate mathematical tool - not just use what they had covered earlier in the chapter.

We began to look for real applications from industry to supplement the curriculum. In so doing, it became obvious that we needed to evaluate the traditional content. The mathematical skills needed by industry cannot be supplied with a traditional algebra-based curriculum. Students must acquire a strong *foundation* (as defined in *CROSSROADS* [1], by AMATYC) in mathematics that must include statistics, modeling, functions, and problem solving.

As we discussed the problem, we found we were not alone. As we discussed solutions to the problem, we found there were many. However, there were some catalysts for change.

3. Catalysts for Change

3a. Scans

The 1991 report, **What Work Requires of Schools: A SCANS Report for America 2000** (http://www.stolaf.edu/stolaf/other/extend/Resources) (SCANS: Secretary's Commission for Achieving the Necessary Skills), provided guiding principles for career-oriented curricula. SCANS calls for all courses to strengthen the skills the student will need as a graduate--in the workplace. In addition to the basic skills the student will need, SCANS calls for students to acquire *Thinking Skills* and positive *Personal Qualities*. The three-part foundation is measured by five competencies: (1) ability to use resources, (2) ability to work with others, (3) ability to acquire and use information, (4) ability to understand complex interrelationships, and (5) ability to work with a variety of technologies.

As a result of SCANS, we began to include more complex projects in mathematics courses. The projects were based on applications from other areas (civil, mechanical, electrical…) and required the students to work in teams and to make a joint presentation to the class, in addition to the written report. Also, we began to use more technology (graphing calculators and spreadsheets) more often in the classroom.

3b. Technology

More than any one thing, the availability of hand-held graphing/programmable calculators has changed the environment of the mathematics classroom. Problems don't have to be 'nice', and the chalkboard is not the only way to convey graphics. Students are more active participants in the learning experience.

We began to require students to have and to use graphing calculators in the early 90s. Today, most courses require the calculator, unless the students work on a spreadsheet. We believe that we should move toward spreadsheets since they are the technology of choice for most businesses. It seems that in industry, spreadsheets are as common as coffee cups. Students should practice using technology as a mathematical tool in their classroom.

3c. Crossroads

In the mid 90s, AMATYC began work on **Crossroads in Mathematics: Standards for Introductory College Mathematics Before Calculus** (http://www.amatyc.org). The final product, building on the work done by NCTM [3], established recommendations for undergraduate mathematics. The document contains three sets of standards: for *Intellectual*

*Deve*lopment, for *Content*, and for *Pedagogy*. The publication interprets the standards as they relate to various program areas, including the mathematics for *Technical Programs*.

Crossroads provided motivation and evidence for changes in the mathematics curriculum. Some content was covered to a lesser extent or deleted, other content was covered to greater depth, and some content was added. Specifically, more statistics was added to introductory courses. Faculty used the "rule of four" in their teaching. That is, content is explained using *symbols*, *graphs*, *tables* and *words*. In addition, faculty began to use a variety of methods to evaluate the amount of learning going on in the classroom.

4. Support for Change

The workload of two-year college faculty was a barrier to change. We found it necessary to seek support from outside agencies to fund reassigned time for faculty to work on changing curriculum and improving pedagogy.

4a. Integrated Curriculum

Faculty searched for real applications to supplement the mathematics curriculum. Applications were used to write one-day classroom activities and longer projects. However, the math sections contained students with a variety of majors. Discipline-specific applications that would appeal to most students were difficult to find. The solution was to use physics to apply the mathematics. By integrating the two subjects, we believe we can teach content more effectively and efficiently. With support from the National Science Foundation (NSF ATE: 97-52038, 99-50101), faculty began to work on integrating the mathematics and physics courses offered to some engineering technology curricula. The integrated curriculum provides immediate applications to the mathematics. (http://www.wake.tec.nc.us/math/chimp97.html) These applications provide motivation for the study of the mathematics content as well as encouraging a deeper understanding of the content. The courses were constructed by letting the physics drive the curriculum with the mathematics taught “just-in-time.“ Students work cooperatively as they develop their own process for doing “lab activities” that often require them to collect and analyze data and to explain their results. The investigators developed an elicit-confront-resolve-assess model for classroom activities. The instructor acts more like a coach or facilitator.

As faculty constructed the curriculum, difficult decisions were made regarding the inclusion of course content and the degree to which the content is covered. The decisions were made with input from technical faculty, from industry practitioners, and from colleagues in mathematics and physics.

4b. Workplace Research

In an attempt to understand how and what mathematics is used in industry, faculty visited industries that employ technical graduates. As part of the college’s Tech Prep effort and with support from the National Science Foundation (NSF ATE 95-53709, 00-71093), faculty performed research in the workplace to find applications of mathematics. (http://www.wake.tec.nc.us/math/wr95.html) The goal of the project was to write materials for faculty to use in the classroom (K-12 and two-year college). However, a secondary consequence was the motivation for faculty to use appropriate technology, specifically spreadsheets.

Visits to industry were made during 1994-96. We found industry in the midst of transition. More was being expected of workers as elements of TQM were being implemented and technology enabled information to flow quickly from the assembly line to the managers to the customers. Teams visited large global companies like Siemens, Glaxo Wellcome, Square D, and Mallinckrodt, as well as smaller companies and government agencies.

A more elaborate attempt to define the needs of industry was begun in the summer of 2000. Faculty contacted industries, which employed two-year graduates as technicians and asked for permission to interview several employees. A lead team of two or three faculty then visited the industry to conduct the beginning phase of the workplace research. First, the team had to locate the employees who were knowledgeable concerning the work of technicians. These interviews led to subsequent visits with technicians during which the technicians and the team isolated the application(s). A video clip of the technician discussing their job and their use of math was included in the snapshots. Students and faculty have a better acceptance of the research when they see and hear the employees speaking. The full team (six to eight faculty) would then research and write about the applications that would eventually be highlighted in the snapshot. Faculty found industry very eager to cooperate and willing to invest the time to contribute to a better curriculum. The visits during the summer of 2000 supported the observations made during the earlier project. We also found that the best technicians were employees with a wide repertoire of skills who continued to take classes and improve their technical and communication skills.

Teams constructed "mathematical snapshots" that provide information about the industry, about the employee, and about the application. These snapshots, on CD, have been distributed to high school and two-year college faculty. Technology faculty were consulted and encouraged to add material that related to their curriculum. Conversations among math and physics faculty and technical faculty helped to evaluate the merit of content in courses.

4c. A National Effort

The MAA [2] is currently evaluating the undergraduate mathematics curriculum. The project is under the direction of the CUPM (Committee on the Undergraduate Program in Mathematics) subcommittee and is called CRAFTY (Calculus Reform And the First Two Years) (http://www.maa.org/news/cupm.html). AMATYC submitted a proposal to the National Science Foundation for financial support to examine the mathematics required of students in the emerging technologies. The grant, Technical Mathematics for Tomorrow: Recommendations and Exemplary Programs (NSF ATE: 00-03065), was awarded in September of 2000 (http://www.wake.tec.nc.us/~rlkimbal/CRAFTY.htm).

Two workshops were held in October. About 50 technical faculty and industry practitioners participated in either the Los Angeles or the Richmond workshop. They made recommendations on the content of mathematics in four technical areas: (1) Information Technology; (2) Biotechnology and Environmental Science; (3) Manufacturing, especially semiconductors; and

(4) Electronics and Telecommunications. The recommendations from the Richmond and LA workshops are summarized in four reports and are available from the website. These four reports will be the subject of a national workshop that will be held in September of 2001. The national workshop will enable faculty who teach mathematics to evaluate the reports and talk with some of the participants from the earlier workshops who wrote the reports. The result of the national workshop will be recommendations

- for implementing procedures and processes,
- for using technology and pedagogy, and
- for developing curricula and courses that will improve the mathematics education of technicians.

5. Outcomes and Findings

The outcomes can be categorized by how they affect Faculty, Students, Pedagogy, Content, and Curriculum.

5a. Faculty

Faculty found the visits to industry rewarding. They liked being treated respectfully and professionally. They were motivated to learn more about how mathematics is used in industry and were excited about describing their experiences in the classroom.

5b. Students

Students benefit from the rich applications they are provided. The applications are written in context and have a direct connection to industry. Students acquire the skills needed to succeed in a high-tech, global workplace.

5c. Pedagogy

Students are required to work in teams on problems that are less structured and require the team to address the process for solving the problem. The content is often application-driven, using short problems and even case studies to motivate the subject. Students are required to make written reports and oral presentations on their findings. Technology (calculators and computers) is used as a tool for instruction and for problem solving

5d. Content

There are six general observations about what employees need to be able to do. Employee's need to:

1. Be able to use basic skills in measurement, estimation, algebra, and geometry.
2. Be able to read and interpret statistical data.
3. Be able to read, interpret, and communicate technical information.
4. Be able to think critically.
5. Be able to use technology.
6. Be able to work effectively in teams.

5e. Curriculum

The most difficult outcome to implement may be the development of a curriculum that promotes the other outcomes. It is evident that the curriculum must be integrated so that supporting courses in mathematics, science, and communication aren't viewed as independent academic hurdles that students must surmount. Rather the content is covered "just-in-time" or supplements the study of the technical content. The curriculum may spiral through content, covering it more in-depth each visit. Portfolios and/or Capstone Projects http://www.wake.tec.nc.us/curred/et/Capstone/index.htm) are used to validate the student's achievements. The curriculum must be kept current by continuing communication with technical faculty and industry practitioners.

6. Assessing Change

The partnerships established among faculty to construct a meaningful and useful mathematics curriculum also provide a means of assessing how well the curriculum meets the needs of technology faculty. Faculty should develop mechanisms for continuous improvement with input from a number of areas.

It is important for mathematics faculty to be aware of (1) the needs of graduates for immediate success, (2) materials constructed through support from outside agencies, (3) recommendations that are made by professional societies, and (4) the needs of citizens who wish to be life-long learners. This is done through continuing involvement in professional organizations, technical faculty, and industry. Math and physics faculty now are included on advisory committees for the technical programs. These meetings provide a setting for industry practitioners and technical faculty to interact.

Bibliography

1. American Mathematical Association of Two-Year Colleges. (1995) Crossroads in Mathematics - Standards for Introductory College Mathematics before Calculus. Memphis, Tennessee.
2. Mathematical Association of America. (1993) Guidelines for Programs and Departments in Undergraduate Mathematical Sciences. Washington, DC.
3. National Council of Teachers of Mathematics. (1989) Curriculum and Evaluation Standards for School Mathematics. Reston, VA.

Robert L Kimball

Robert Kimball has served as department chair for the Mathematics and Physics Department at Wake Technical Community College since 1981. He earned both his BS (1973) and MS (1981) at North Carolina State University in Mathematics Education. He has served AMATYC as chair of the Technical Mathematics Committee (1991-1997) and as a member of the writing team for Crossroads. AMATYC awarded Robert the Teaching Excellence Award for the Southeast Region in 1998. He was the founding President of the North Carolina AMATYC affiliate and now serves as the newsletter editor for NCMATYC.