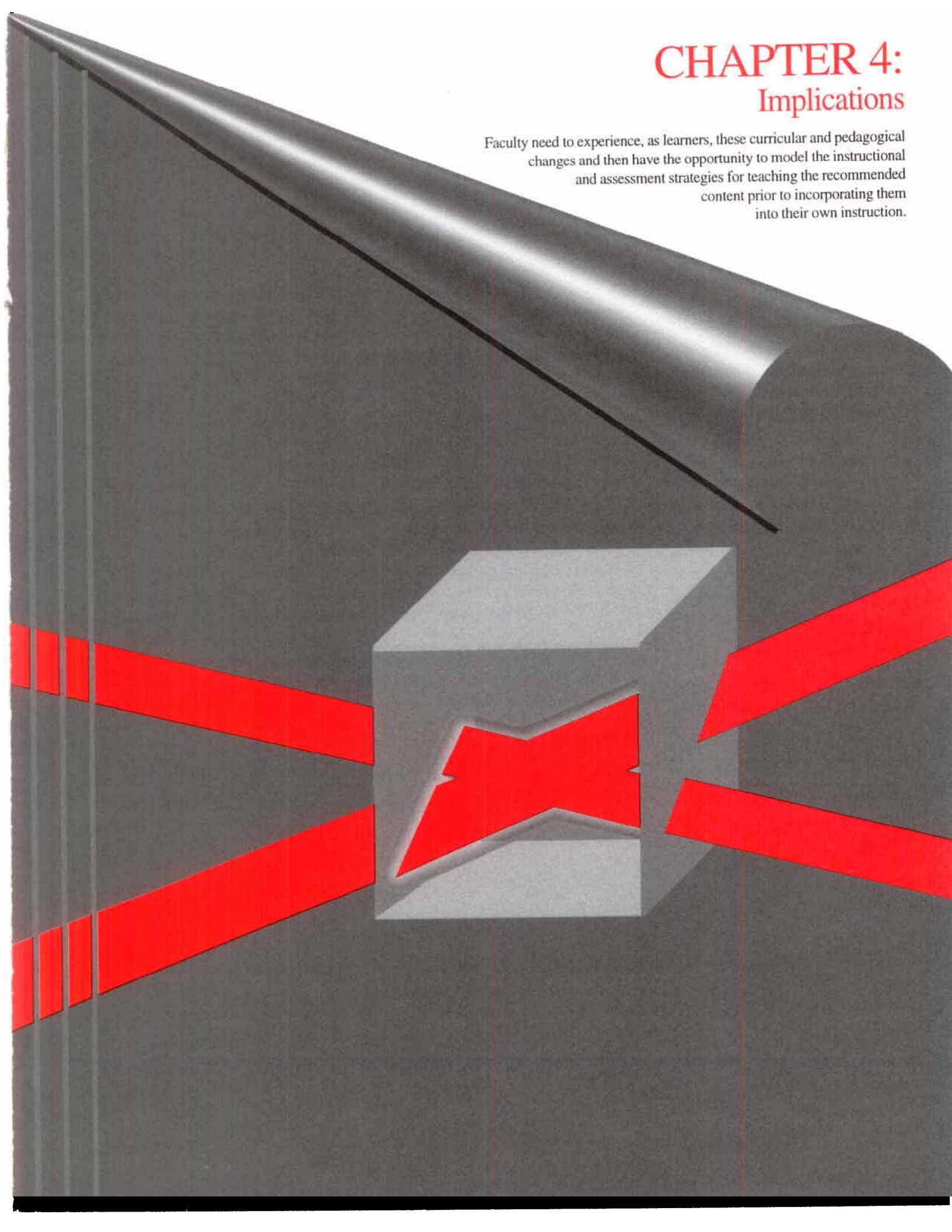


CHAPTER 4: Implications

Faculty need to experience, as learners, these curricular and pedagogical changes and then have the opportunity to model the instructional and assessment strategies for teaching the recommended content prior to incorporating them into their own instruction.



Although the standards for introductory college mathematics presented in Chapter 2 focus on curriculum and pedagogy, they have wide implications for institutions and their mathematics programs. This chapter presents a brief summary of recommendations on faculty development, advising and placement of students, instructional facilities and technology, assessment of students, program evaluation, and articulation among colleges and with high schools.

FACULTY DEVELOPMENT AND DEPARTMENTAL CONSIDERATIONS

The standards set forth in this report mandate a complete restructuring of content and instructional strategies. While the standards emphasize meaningful mathematics and active student participation in the learning process, the college education of most current faculty emphasized algorithmic procedures and lecturing. Faculty need to experience, as learners, these curricular and pedagogical changes and then have an opportunity to model the instructional and assessment strategies for teaching the recommended content prior to incorporating them into their own instruction. Professional development opportunities must be made available to every faculty member—full-time, adjunct, and teaching assistant.

In addition, institutions should provide regular, sustained release time and other resources to support the professional development of faculty. As stated in *Moving Beyond Myths* (NRC, 1991), faculty need to “think as deeply about how to teach as about what to teach” (p. 34). Resources must be provided so that faculty can establish ongoing professional development programs on campus to meet their special needs, as well as attend off-campus professional meetings, seminars, workshops, and courses so that they can interact with colleagues from other institutions.

The instructional process recommended in this document must be designed and implemented by knowledgeable, caring, effective faculty. According to *Guidelines for the Academic Preparation of Mathematics Faculty at Two-Year Colleges* (AMATYC, 1992), effective teachers are reflective, creative, and resourceful. They use a variety of instructional methods and respond to the needs of the particular students they are teaching. Furthermore, they model behaviors they wish their students to exhibit and treat their students and colleagues in a caring and helpful manner. Faculty must provide careful academic advice, be flexible about ways in which students can meet course requirements, and simultaneously provide support to and demand commitment from their students.

While it is not the purpose of this document to offer a complete set of guidelines for the operation of mathematics departments, faculty should become familiar with and implement the recommendations of the AMATYC documents, *Guidelines for the Academic Preparation of Mathematics Faculty at Two-Year Colleges* (AMATYC, 1992) and *Guidelines for Mathematics Departments at Two-Year Colleges* (AMATYC, 1993), and the MAA's *Guidelines for Programs and Departments in Undergraduate Mathematical Sciences* (MAA, 1993). Some conclusions of these documents are

"A craft is a collection of learned skills accompanied by experienced judgement. The great advantage of thinking of teaching as a craft is the recognition that anyone can learn it. Competent teaching requires no special gift, no actor's personality, no divine spark. And if anyone can learn to be a competent teacher, then all who are employed to teach have the obligation to learn."

David S. Moore. From his remarks on receiving the MAA's 1994 Award for Distinguished College or University Teaching of Mathematics, San Francisco, January 1995. Printed in *Focus*, April 1995.

"As a general perspective, I feel too many mathematics teachers act as if they are teaching students who are what they think they were at age 18. One catch is that few, if any, of us really remember what we were like 20 or 30 years ago. Further, we lose sight of the fact that 98% of the students around us at that time never went on to careers in mathematics or science, nor should we expect that much more than 2% of our current students will. . . . We must recognize that we are addressing a much broader audience who is not motivated by what may have motivated us and we must adapt our offerings accordingly."

Sheldon Gordon,
Suffolk Community College

"Research into how students learn mandates the changes in pedagogy. The demands of the real world mandate the curricular changes."

Task Force

- Faculty members should be aware of and use advances in mathematics content and educational methods.
- Those who teach mathematics either in mathematics departments or in departments of developmental studies at two-year colleges should have a minimum of a master's degree that includes at least 18 semester hours of graduate work in mathematics.
- Classes must be held in a suitable environment. They must be a reasonable size (a maximum of 30 with fewer in foundation classes) to enhance the opportunity for the use of interactive learning strategies.
- Classrooms should be equipped so that computer instructional material and calculator outputs can be displayed. Computer laboratories should be available for student use.
- Adequate support services outside of class must be made available to students. Support services should include faculty who are available in their offices on a regular basis to help students, learning centers that offer professional and peer tutoring, and technology specialists who can help students in computer laboratories.
- The administrator of the department should be aware of the standards, promote new ideas and experimentation, and facilitate the establishment of appropriate learning environments. Opportunities should be provided for faculty to discuss anticipated changes.

A major concern in two- and four-year colleges and universities is the access of students in introductory college mathematics courses to full-time faculty. A sizable segment of this curriculum is taught by graduate students at universities and by adjuncts at two- and four-year colleges. An excessive dependence on instructional personnel who may not contribute to curriculum development, advising, and other department responsibilities and who may not be available to provide students with help outside of the classroom can place undo hardship on a department and on the students.

Both AMATYC (1993) and MAA (1993) recommend that adjunct staffing should be kept at a minimum. When used, such faculty should have the same qualifications as full-time faculty. They should participate in professional development activities, they should be kept fully informed of departmental activities and policies, and they should be included in departmental activities whenever possible. The MAA (1993) recommends that graduate teaching assistants be closely supervised by full-time faculty.

The limited use of adjunct faculty can enhance mathematics education in some circumstances. Adjunct faculty whose full-time employment involves applying mathematics can bring special expertise and breadth to the department's offerings. In addition, adjunct faculty who are regularly employed in other area institutions bring a fresh perspective to the department and may provide an interface between local high schools and postsecondary institutions.

Faculty who have already begun to incorporate the proposed standards into

their teaching report that some students feel uncomfortable with the deviation from “traditional” instruction. Even students who have, by and large, been unsuccessful learning in a traditional classroom resist change. Faculty must be prepared to smooth the transition as much as possible by

- providing students with detailed instructions to clarify faculty expectations of them,
- forming student study groups and resource centers specifically designed to help students understand the changes being instituted,
- listening to student concerns and frustrations expressed orally or in writing and following their suggestions where advisable,
- providing students with evidence that the changes will enhance their learning, and
- offering students alternatives, with traditional instructional strategies occasionally being the alternative.

In addition, faculty need the support of a learning center as a source of tutoring and other forms of student assistance, especially for times when faculty are not available. Learning centers should also provide a setting for students to work in groups. In this regard, learning center staff must also be knowledgeable of the standards for introductory college mathematics so that instruction received in these centers is in concert with classroom procedures.

“Revitalizing and reforming undergraduate mathematics education is one of the principal challenges facing the profession today” says the report *Recognition and Rewards in the Mathematical Sciences* (Moore, 1994). One of the report’s guiding principles states: “Each department should ensure that contributions to teaching and related activities and to service are among the primary factors of importance in the recognition and reward system” (p. 30). It is critical that institutions reward faculty for their active involvement in curricular and pedagogical reform.

ADVISING AND PLACEMENT

“Departments should have established policies and procedures for placement into introductory mathematical science courses. It is important that these policies be well understood and disseminated across the institution” (MAA, 1993, p. 9). Placement testing should be applied equitably to all students and must be statistically valid so that students have the opportunity to be successful, as well as challenged in their coursework. Implementation of the standards advocated in this document and the reform taking place at the high school level make it imperative that new placement tests, consistent with these initiatives, be developed and continually updated as further revisions in curriculum and pedagogy occur and new technologies are used. Placement tests should include questions that do more than merely test the students’ mastery of algorithmic skills. They should provide measurements of students’ abilities to think critically, use technology,

“Students were assigned mathematics laboratory experiments for which they wrote laboratory reports. This type of work was new to them and they indicated great frustration with the assignments. The professor revised his course procedures to include very specific instructions for writing such reports and included a sample laboratory report from a previous semester. Difficulties for later students were diminished.”

Task Force

“The goal of any placement program is to place students into courses in which they will be successful and challenged.”

John Jenkins, Embry-Riddle
Aeronautical University

solve problems, and communicate about mathematics using a variety of methods.

Placement procedures should include more than review of students' high school records, college entrance examinations, and appropriate mathematics placement tests. Students should have the opportunity to meet with faculty to discuss how their proposed placement relates to their educational, career, and personal goals. Final decisions on the proper placement of students in mathematics must be made by the mathematics department in conjunction with the student.

Students should also receive general academic advising. Faculty act as advisors at some colleges, while on other campuses special counselors do all the advising. When faculty are involved in advising, they should receive training and appropriate compensation for these duties.

Advising is generally associated with such activities as helping students select courses and checking to be sure that degree requirements are satisfied. However, changes in the collegiate student population—more returning adults, more academically underprepared students, more who are the first in their families to attend college, and so forth—necessitate increased emphasis on advising. In addition to the traditional duties of an advisor, the following matters should be considered:

- identifying students with learning disabilities and using the assistance of relevant campus agencies,
- disseminating information about career opportunities involving mathematics,
- providing students interested in mathematics with the opportunity to meet in an informal setting with faculty and other students with the same interest,
- providing enrichment activities for mathematics students, and
- addressing the learning needs of a culturally diverse student population.

LABORATORY AND LEARNING CENTER FACILITIES

This document advocates the use of mathematics laboratories in the teaching of mathematics. A mathematics laboratory should provide students with activities designed to guide them in the construction of their own understanding of mathematical concepts, strengthen their ability to critically apply mathematics, and encourage the use of a variety of skills and content to solve nontraditional problems. Students should work in groups, use cooperative learning strategies, and communicate what they have learned either orally or in writing. A variety of tools and techniques should be used in the laboratory, including faculty demonstrations and hands-on student work with manipulatives, data gathering instruments, graphing calculators, and computers.

In addition to calculators, computers, and other technological tools, an effective laboratory environment includes helpful instructional staff members and movable furniture to facilitate group activities. Colleges must budget adequate funds to hire and train needed staff and to purchase and maintain appropriate equipment as well as allocate the necessary amount of space for mathematics

A mathematics laboratory should provide students with activities designed to guide them in the construction of their own understanding of mathematical concepts, strengthen their ability to critically apply mathematics, and encourage the use of a variety of skills and content to solve nontraditional problems.

laboratories. The addition of a laboratory component should not be used as an excuse to add more topics to the curriculum. Rather, it should be used to enhance understanding of the topics faculty have decided are important for students to learn.

Mathematics programs should also include a learning center facility, staffed by professional and peer tutors, where students can gather to get extra help, work on assignments, and socialize. In addition, the facility can serve as a home base for a mathematics club, a library, and an area for informal faculty and student interaction.

TECHNOLOGY

Technology is changing and will continue to change the way mathematics is done around the world. Almost every research study on the use of calculators or computers in the classroom reports that “the performance of groups using calculators equaled or exceeded that of control groups denied calculator use” (MSEB, 1990, p. 22). For example, Dunham and Dick (1994) reviewed research on the classroom use of graphing calculators:

The early reports from research indicate that graphing calculators have the potential dramatically to affect teaching and learning mathematics, particularly in the fundamental areas of functions and graphs. Graphing calculators can empower students to be better problem solvers. Graphing calculators can facilitate changes in students' and teachers' classroom roles, resulting in more interactive and exploratory learning environments. (p. 444)

Computers, graphing calculators, educational television, computer-based telecommunications, video discs, and other technological tools and related software should be fully utilized in college classrooms [see Dunham (1993), Dunham and Dick (1994), Foley (1990), and Leitzel (1991)].

Although most students can afford to purchase their own graphing calculators, colleges should establish lease or loan programs for needy students. In addition, adequate funds must be allocated by colleges to purchase other technological resources.

Technology that enhances learning is available, and students will use it whenever they realize its power, regardless of whether professors allow it in their classrooms. Mathematics faculty must adapt to this reality and help students use technology appropriately so that they can be competitive in the workforce and adequately prepared for future study.

ASSESSMENT OF STUDENT OUTCOMES

Assessment must be viewed as an integral part of instruction. Mathematics faculty must use assessment strategies that not only determine the extent of student learning but also support student learning. Furthermore, the assessment instruments must measure the full range of what students are expected to learn, not just what is easy to measure. Assessment should build excellence into the educational process by providing regular feedback to students and faculty about learning and instruction.

**"With technology—
Some mathematics
becomes more
important.
Some mathematics
becomes less
important.
Some mathematics
becomes possible."**

Henry Pollak (Retired),
Bell Laboratories

**"The assessment procedures
should do justice to the goals
of the curriculum and to the
students—context
independent generalized
testing is unjust when for
instruction the context
includes the real world of
mathematics itself, at least in
the realistic mathematics
education approach. An
essential question is: 'Does
assessment reflect the theory
of instruction and learning?' "**

Jan de Lange in
*Selected Lectures from the 7th
International Congress
on Mathematics Education*
(Quebec, August 17-23, 1992), p. 235.

"Organizing my portfolio gave me a wonderful opportunity to evaluate my progress. When I compare where I am now with where I was, mathematically, at the semester's beginning, I am very proud of myself! My confidence in my ability has continued to grow throughout the semester, and I've actually reached the point where I enjoy the challenges presented to me instead of becoming instantaneously defeated."

A student's comments

As curriculum standards, instructional strategies, and student outcomes change, effective standards for assessment and accountability must follow. A new national understanding of assessment must be built upon the fundamental principles presented in such publications as *Measuring Up* (MSEB, 1993), *For Good Measure* (MSEB, 1991), *Assessment Standards for School Mathematics* (NCTM, 1995), and *Assessment of Student Learning for Improving the Undergraduate Major in Mathematics* (Madison, 1995).

Expanded views of the more traditional forms of assessment are needed. For example, a variety of forms of testing should be used—essay, short answer, open-ended, and multiple-choice questions, and oral as well as written exercises and problems. Furthermore, group testing is particularly appropriate for students who are accustomed to working in groups during regular course activities. Students should also be expected to write essays, do boardwork, do group projects and laboratory reports, and make oral presentations. Assessment instruments should measure not only students' knowledge of mathematics content, but also their ability to solve problems, to communicate, to work in groups, and to read technical material.

Students should use technology on virtually all tests just as they do in regular coursework. At the same time, students should be held accountable for learning certain basic skills. One assessment technique involves identifying a competency set of basic skills to be mastered. Students must achieve competency (say, 90%) on a "gateway" test (taken without calculators or computers) or they do not pass the course, regardless of their performance on other assessments. They may retake the test at given intervals until they pass. This reinforces the message that certain skills are mandatory and essential. (See Megginson, 1994 for a description of and research on the gateway testing program at the University of Michigan.)

Portfolios can be used to make general assessments of student learning. A student's mathematics portfolio is similar to an artist's portfolio, containing representative samples of all assessment instruments used in class. These might include quizzes, examinations, homework, laboratory and other written reports, copies of group projects, as well as notes or videotapes from oral presentations and teacher-student interviews.

Just as many of the recommended assessment techniques will be new to some faculty, they will be new to some students. Whatever mix of assessment instruments are used, it is of paramount importance that students be fully informed about the manner in which performance will be assessed.

All activities that are part of the learning experience should be a part of the assessment of that learning. Good assessment practices should be indistinguishable from good instructional practices. The assessment instrument or method is not the end product of learning but rather part of the learning process.

PROGRAM EVALUATION

The effectiveness of any mathematics program depends on its ongoing revision and revitalization based on regular evaluations. The intent of any program evaluation should be to make recommendations for improvement and updating while retaining the effective aspects of the program.

Although mathematics faculty should carry the primary responsibility for program evaluation, comprehensive information about the mathematics program

The intent of any program evaluation should be to make recommendations for improvement and updating while retaining the effective aspects of the program.

should be collected from all areas affected— faculty, students, administrators, and community or employer advisors. Whoever directs the evaluation should collect information that identifies strengths, weaknesses, and recommendations for improvement. In addition, the evaluation should include periodic discussions with graduates of programs and their employers to determine the effectiveness of these programs in meeting the needs of business, industry, and the community. Nearby high school teachers and mathematics faculty from surrounding colleges and universities should also be surveyed. Such coordination of instruction across institutions will foster better articulation from one program to another and ensure more consistent mathematical experiences for the students.

The standards for intellectual development, for content, and for pedagogy contained in this document should serve as criteria for evaluation of the instructional aspects of programs. Furthermore, a review of faculty and support staff, physical facilities, equipment, and supporting materials is important to determine whether they are appropriate to and sufficient for the objectives of the program. Program evaluation should also include review and evaluation of assessment methods.

ARTICULATION WITH HIGH SCHOOLS, WITH OTHER COLLEGES AND UNIVERSITIES, AND WITH EMPLOYERS

Educational reform must not be done in isolation. The formation of local consortia of high schools, colleges, and universities enables mathematics faculty at all levels to work in concert to improve mathematics education. Representatives from industry, business, and government who are the future employers of college graduates should be included as full partners in educational reform. The practitioners in the field and from client disciplines can provide vital up-to-date input on mathematical methods and problem solving strategies that they use. Such cooperation provides continuity in the educational experiences of students from high school to postsecondary institutions and between such institutions with better uniformity and consistency both in content and approach. Secondary and postsecondary institutions should work together to assure students entering each level of mathematics in postsecondary education that their preparation is appropriate for that level.

One reform project, the Maricopa Mathematics Consortium (M²C), has built a working consortium of five local high school districts, the ten Maricopa County colleges, and Arizona State University. The consortium will develop and implement a complete curriculum for introductory college mathematics based on the theme "mathematics in context." They are developing partnerships with other disciplines, as well as with local business and industry, to clarify the contexts in which people use mathematics to understand the world better. The collaboration between educational levels serves to advance curricular change at each level.

Crossroads in Mathematics takes a strong stand on what mathematics is important for students to learn, thereby raising important questions about articulation. Will students who participate in an introductory college mathematics program that is guided by the standards have difficulty if they transfer into a traditional mathematics program? Will the lack of emphasis on symbol manipulation skills impede students? While it is too soon for extensive research to be available on current reform initiatives, there is evidence to suggest that

The formation of local consortia of high schools, colleges, and universities enables mathematics faculty at all levels to work in concert to improve mathematics education.

transfer problems should not be a major obstacle.

For example, F.S. Gordon (1995) compared the algebraic skills of students using the NSF-funded Math Modeling/PreCalculus Reform Project course materials with those of students using traditional college algebra and trigonometry materials. The group using the reform materials had higher mean scores on six of seven common questions that appeared on final examinations. The differences in means on three of the questions were significant at the 5% level in favor of the reform group. Gordon comments in her paper that the “real” difference in the classes was brought home to her when she was answering homework questions in both classes on one particular day. The reform class raised a question that involved using an exponential function to model population growth in California. The traditional class asked about factoring $(x + 1)^4 - 9$.

Tidmore (1994) compared the performance of students using materials produced by the Calculus Consortium based at Harvard University (CCH) with that of students using a traditional text on a common Calculus I final examination at Baylor University. The CCH materials emphasize educational principles analogous to the standards presented in this document. The results indicated that CCH students had a significantly higher overall performance, and they were higher at each ability level. An analysis of scores on problems from identifiable areas of study indicated that the CCH group did better on problems that were graphical, numerical, or conceptual in nature. On problems that were algebraic or traditional in nature, the scores were very similar.

Bookman (1994) found that, compared to a group of students taught traditional calculus, students in Project CALC at Duke University performed better in many ways: They became better problem solvers, they were observed to be more actively engaged in the study of calculus, and they had higher continuation rates from Calculus I to Calculus II (and from there to more advanced mathematics classes). In addition, there were virtually no differences in their grades in mathematically oriented courses taken after Calculus I. On the other hand, the Project CALC students did less well on computational skills involving symbolic manipulation. The faculty involved felt this problem could be remedied by including more practice on routine calculations.

While these studies do not directly answer the articulation questions, they do point out that students can take reformed mathematics courses without major loss of computational abilities, and they are not handicapped when they study higher levels of mathematics. Furthermore, if students understand mathematical principles and practice independent learning, they should be able to function in a traditional setting.

Communication among educational institutions, between high schools and colleges, and between mathematics and other departments will ease the transition from a traditional to a reformed approach to mathematics education. Documents like this one help to accelerate the pace of reform and look forward to the day when there is no need to ask about articulation problems.

SUMMARY

This document recommends a complete restructuring both in content and pedagogy of introductory college mathematics. Changes in the structure of course offerings and in the content of the mathematics curriculum influence all areas of

Students can take reformed mathematics courses without major loss of computational abilities and they are not handicapped when they study higher levels of mathematics.

instruction. But these changes will flounder without proper support of the faculty who are expected to carry them out. If faculty are given the opportunities and the tools they need to make substantive contributions to the reform effort, they will become effective advocates of the changes that are needed in such areas as advising and placement, facilities, technology, assessment, program evaluation, and articulation.