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ABSTRACT

The University of Wisconsin-Madison is using a novel assessment process to find whether rising juniors have the quantitative skills needed for success in their chosen upper-division courses. Sampling from departments across the campus, information is gathered about quantitative skills used in specific courses and the extent to which students can show these important skills at the start of the semester. Instructors play a key role in helping to design free-response tests reflecting capabilities expected of students from the first week and essential for success in the course. Two important characteristics of this form of assessment are direct faculty involvement and close ties to student goals and backgrounds. It was found that the reflection, contacts, and dialogues promoted by this form of a sessment are at least as important as the test results. This paper briefly outlines the assessment procedure, highlights some findings about instructor expectations and student capabilities, and describes a variety of ways that the program has had a local impact. (Author/MKR)

Linking Faculty Expectations and Student Goals to the Assessment of Quantitative Capabilities[1]

William O. Martin

Abstract

The University of Wisconsin-Madison (UW-Madison) is using a novel assessment process to find whether emerging juniors have the quantitative skills needed for success in their chosen upper-division courses. Sampling from departments across the campus (courses have included *Principles of Advertising*, *Biophysical Chemistry*, and *Circuit Analysis*) information is gathered about (a) quantitative skills used in specific courses and (b) the extent to which students can show these important skills at the start of the semester. Instructors play a key role in helping to design free-response tests reflecting capabilities expected of students from the first week and essential for success in the course. Two important characteristics of this form of assessment are (a) direct faculty involvement and (b) close ties to student goals and backgrounds. We have found that the reflection, contacts and dialogs promoted by this form of assessment are at least as important as the test results. This paper briefly outlines the assessment procedure, highlights some findings about instructor expectations and student capabilities, and describes a variety of ways that the program has had a local impact.

Assessment Perspectives

Assessment in higher education. Assessment in mathematics used to mean tests and grades. In recent years, the kind of assessment that occurs in classrooms has received increasing attention. The National Council of Teachers of Mathematics has led the push for a broader conception of mathematics assessment with the development of *Assessment Standards for School Mathematics* (1993). Indicative of assessment's current high profile, Ewing (1994) expressed uneasiness in the *American Mathematical Monthly* about the lack of precision in the discussion of "something so obviously sensible" as assessment. I expect that many others in higher education, including mathematicians, share his uncertainty about the growing preoccupation with assessment.

Assessment at the institutional and state levels became an important issue during the 1980s (Ewell and Lisensky, 1988); assessment programs have now been mandated for colleges and universities in many states (Ewell, 1994). Accrediting agencies—for example, the North Central Association of Schools and Colleges that accredits the UW-Madison—also have introduced assessment requirements; so, assessment beyond that carried out at the course level will increasingly require faculty attention. Mathematics departments, because of their important service function for undergraduate degree programs, will have an extra role to play in campus assessment programs—this besides their need, like all departments, to assess in the major.

This paper is about the evolution of a quantitative assessment project, run by faculty members in mathematics and statistics, designed to meet external assessment requirements in a way that is useful locally for participants. An important characteristic of the project is its focus on specific needs and expectations of students and faculty in particular courses. The assessment project operates at an intermediate level between the individual classroom and the institution.

Evaluation and assessment. The terms *assessment* and *evaluation* are sometimes used interchangeably, though there is some distinction between them. Angelo (1994) defines assessment as "a means for focusing our collective attention, examining assumptions, and creating a shared culture dedicated to understanding and continuously improving the quality of higher learning" (p. 1). The *quantitative assessment project* at the University of Wisconsin-Madison (UW-Madison), treats *assessment* as the gathering and reporting of information

[1] This paper was prepared for the MAA session on *New Directions in Student Assessment* at the Joint Mathematics Meetings of the MAA and AMS in San Francisco, January 3-7, 1995. Copies of the paper and additional information are available from the author at North Dakota State University, Department of Mathematics, 300 Minard, PO Box 5075, Fargo, ND 58105-5075 (email: wimartin@plains.nodak.edu).

about students' quantitative capabilities without the judgement or valuing of those findings that would be connoted by *evaluation*. To illustrate the distinction, much classroom *assessment* in mathematics contributes to *evaluation* when instructors use information collected on tests and homework to assign student grades.

Quantitative assessment at Madison began for the most familiar reason: it, along with verbal assessment, was externally mandated by the Governor of Wisconsin and the Board of Regents. Amid increasing pressure for accountability in higher education (Ewell, 1991), all system institutions were directed to have programs to assess the quantitative and verbal capabilities of emerging juniors operating by 1991. Although the impetus, and some support, for assessment was external, the form of implementation was left up to institutions.

The concern for faculty involvement in and control of assessment might have the appearance of self-interest. Nevertheless, the importance of faculty involvement is not just a local, faculty concern; Ferren's (1993) call for institutional assessment to be faculty-driven is a common theme in the assessment literature. Scholars working on assessment have noted the lack of educational impact of the widespread use of standardized tests for accountability purposes. For example, the extensive use of various standardized tests for many years at the University of Kentucky-Knoxville appears to have had little impact on instruction or learning (Banta, 1993). Lack of real faculty or student engagement in assessment may explain the missing impact. Such results provide useful lessons for future assessment efforts. Our own findings at Madison agree with Banta's observation:

> Experience over the past decade with assessment at the postsecondary level has indicated that the finding or results obtained from assessment are less important in stimulating improvements in practice than is the process of bringing faculty together to discuss purposes, student outcomes, and methods of instruction as they prepare for outcomes assessment (Banta and Fisher, 1986). (p. 51)

Although quantitative assessment at Madison grew out of institutional assessment and is important at that level, the focus of this report is on its utility for faculty, students, and departments, a perspective that has received much less attention than has classroom and institutional assessment. The assessment procedure we use helps to identity the quantitative needs of students, expectations of faculty, and goals of departments. The information that is generated can help faculty members and departments to improve the instruction and learning of undergraduates (not only mathematics and science majors) at the institution.

Assessment Objectives: Identifying and Meeting Needs and Expectations

Do students enter college (or graduate school, calculus, upper-division courses) with skills required for success? Do grades in prior courses accurately reflect student mathematical capabilities? How good are graduating majors? Do technologies (or writing, group work, hard problems) really make a difference in mathematical learning? As teachers and scholars, we have beliefs about these and similar questions; assessment is a tool to ensure that such beliefs are supported by more than intuition.

Assessment has historically been an important part of higher education. *New directions in assessment* refers both to a change of methodologies used in the classroom and an awareness that assessment is important at other levels beyond individual courses. With several notable exceptions (such as college entrance examinations; statewide examinations such as the New York *Regents'* examinations; and graduate qualifying examinations in doctoral institutions), much less attention has been given to assessment of the impact of programs and sequences of courses. American educational traditions—most notably, the tradition of local control of education—may account for the lack of assessment at this level. In contrast, assessment at a program or institutional level is an important feature in many other nations (for example, in European, Asian, and Pacific countries). There, comprehensive external examinations have significant consequences for students, faculty, and institutions.

In the absence of external assessments, the search for ways to monitor the impact of programs and institutions has turned both outward to commercial testing services (Banta, 1993, p. 39, lists four main instruments) and inward to the institution itself. Within a college or university, three constituencies have a direct interest in quantitative assessment: (a) students, (b) mathematics faculty, and (c) faculty in other "client" departments. Each is likely to have unique reasons for and to use assessment differently. To be locally worthwhile, assessment should address the needs of each group.

Student needs & expectations. Students play a central role in assessment. Often, though, their role is simply as a source of data: students take the tests, complete assignments, or are interviewed. Traditionally, they do not use the data they generate. Assessment can serve a broader purpose for students than just a tool for evaluation and certification. They have expectations and goals that they bring to college; these may change as they progress through their degree program. Mathematics curricula reflect what faculty believe students need to know. To what extent do students provide information about their own perceptions of needs or the extent to which these needs were met by mathematics courses or programs? Mostly, not at all. Are the views of students important? Or should they accept what is offered by educational experts? I believe that student views are very important, especially as they reveal differences between the *intended* and the *perceived* or *received* curricula.

Mathematics faculty expectations. It is interesting that faculty members in a subject founded on deductive rationality can show a willingness to base curricula and teaching on personal experiences and intuition instead of findings from educational research. A useful exercise is to think about the range of individual and departmental innovations or changes in mathematics over the past decade. How many were based on careful analysis of institutional or departmental goals and data about the extent to which these goals were being met? How many reforms were formally evaluated? What is *known* (as opposed to *believed*) about the impact of changes on students? I am fascinated by some of the thoughtful electronic discussions that take place on the American Mathematical Society e-math *calc-reform* discussion group; I have also been struck by the lack of evidence cited in these discussions to support even plausible claims about the benefits of instructional approaches. As mathematicians, we should discuss and specify our own goals for (undergraduate) courses and assess the extent to which they are being achieved.

Client department faculty expectations. Faculty members from across a campus expect students to come into their courses and programs with certain quantitative capabilities. We have found that in non technical courses faculty may initially say they do not use any quantitative material; during further probing, we often discover that they have a variety of basic quantitative expectations that they had not consciously been aware of (e.g., using percentages, reading tables, and interpreting graphical representations). Most mathematics faculty members have heard comments or even complaints about the mathematical capabilities of students in other departments; perhaps even they have had similar feelings about the mathematical preparation their own students bring from high school. What capabilities do faculty in other departments need from their students? Do mathematics prerequisites match these expectations? Do students have the necessary capabilities when they get to the courses? It seems that much of the information about these questions is anecdotal.

External constituencies. In return for their financial support, parents, taxpayers, legislators and others have shown a desire for evidence that supports claims made for higher education. A problem with external calls for accountability is that the impact of higher education is not easily measured; measures that are easily comprehended and compared, particularly from standardized tests, may bear little relation to the goals of the participants in a particular institution.

How can information from such diverse perspectives be collected? Madison's assessment plan is designed to meet external assessment requirements meaningfully, simultaneously providing useful information for student and faulty participants. The focus is on emerging juniors. Included in this group are students who last studied mathematics in high school along with those who have completed two years of extensive study in physical sciences and mathematics. Clearly no standardized instrument could match the quantitative backgrounds of all juniors on this campus. In our project, the link between faculty expectations and student backgrounds is made by tying assessment to student course choices at the junior level. This is when students move from general education to upper-division specialization in the major field. Patterns of results across a range of courses provide evidence about whether students on this campus generally have developed adequate quantitative (and verbal) capabilities to deal with the specialized work in the major. Because students choose major programs and courses, our assessment reflects their goals and backgrounds.

Quantitative Assessment: Gathering, Organizing, and Disseminating Information

Assessment begins with questions. Once the purpose of assessment — that is, the audience and reasons for assessment — has been identified, one must decide what information should be collected. When we talk about how courses or programs contribute to learning, we assume, implicitly at least, some goals or expectations against which to measure achievement or progress. Course descriptions include information about goals, as do departmental statements (such as might be found in college bulletins). Commonly, such documents focus on what will be covered in a course rather than the capabilities that students will develop. As guides for assessment of the impact programs on student learning and knowledge, these statements of goals have little value because they either are closely tied to individual courses or are too broad and content focused. Students study mathematics for myriad reasons; other departments require mathematics for varied purposes; all faculty members do not even share unique goals for undergraduate programs (Boyer, 1990) or, in particular, mathematics. All of this further complicates the articulation of objectives for assessment.

Our assessment process begins by choosing junior-level courses from departments across the campus. Instructors are asked to identify the quantitative capabilities students will need to succeed in their course. With their help, we design a test of those skills. Students take the test early in the semester; corrected papers and information about class performance are returned within a week.

Test construction identifies goals. Identification of goals is built implicitly into the Madison assessment process; faculty articulate quantitative expectations that are closely related to specific courses as they help us construct the quantitative readiness test for their course. As they do this, instructors identify the quantitative skills students need to be successful during the semester. By design, our tests reflect material that students will use during the semester, content that the instructor does not plan to teach and that students should already know. This is not generally an easy task but the attempt to identify specific, necessary capabilities, as opposed to a more general "wish list," is one of the most valuable parts of the assessment exercise.

Motivation is a key issue. A significant problem with assessment outside the context of a specific course is getting students (and faculty!) to participate seriously. Our assessment method is designed to be useful to faculty and students; getting individuals to focus on specific needs and expectations is what gives meaning to the test outcomes. The attitude of instructors is crucial to the success of the exercise. We emphasize to participating faculty members that *the way they portray the test to students* is the most important factor in whether the students' efforts on the test provide useful information for anyone (including the institution). Few students will buy the "Do this for the good of future students and the institution" line. The best approach, we have found, is for the *instructor* to tell students

- The test does *not* count toward their grade, *but*
- Test results will help these students know their quantitative readiness for the course early in the term
- The instructor is very interested in how they do, so it is crucial that students try their best
- Results of the test may lead to course modifications to match content to student capabilities better

Obviously, the instructor needs to believe this --there is little to be gained by trying to assess in a course where the instructor does not, so we do not (naturally, we do try to convince skeptics since it is not uncommon for faculty to doubt the value of assessment initially). Although the process generates information that should help improve courses and programs across the campus, the focus in each course is on the immediate benefits for participating students and instructors.

We have developed a reliable coding scheme that allows mathematics graduate students to record information about student performance on scantron sheets for later analysis so that corrected test papers can be returned to students within a week. Graders rate the degree of success for each problem using a five-point scale; they also code information about the steps students take toward a solution (e.g., differentiated correctly or devised an appropriate representation). We return the corrected test papers along with test solutions and references to textbooks that could be used for review.

Although we do compute (but do not report to students) a test score for each paper (the number of problems they had completely or basically correct), the main focus is on the proportion of the class that could do each problem. This information is clearly useful for instructors; across a series of courses there are patterns in the results that provide useful information for departments, colleges and divisions, and the institution. Our methodology addresses the problem of how to match assessment to student backgrounds by linking assessment to courses selected by students as they begin work in their major. Still, even within a course there can be considerable variability in student quantitative backgrounds. We obtain information from university records about the mathematics and statistics that students have taken. Without identifying individuals, we report this information, along with the assessment test score, to course instructors.

Discussions with faculty. Faculty contacts are central to this form of assessment. The validity of our findings is dependent on instructors ensuring that the test we design accurately reflects the quantitative prerequisites for their course. For the assessment to have local value it is necessary that findings are circulated among and discussed by individuals and groups with an interest in students' quantitative capabilities who can respond to the results. This is at the crux of the Madison assessment strategy, and is an important contrast with standardized testing. It is worth emphasizing that the main advantage of this approach is in the ongoing dialog about student knowledge and learning that is promoted, indeed required, to conduct the assessment:

- Individual faculty members must focus on specific expectations for a course to prepare an appropriate test.
- Student needs and backgrounds are reflected in the assessment process because the test is tied to a course the student has chosen, usually at the start of their studies in the major.
- Faculty from mathematics, statistics, and client departments talk about faculty expectations, student needs, and student performance in relation to specific courses and programs.
- The conversations are tightly focused on the reality of existing course content and written evidence from students about their quantitative capabilities.
- Everyone involved, students and faculty, gains useful information that has immediate significance apart from its broader, long-term institutional meaning.

Findings

Our assessment work has produced some surprising results, thought it has not generally revealed large discrepancies between instructor expectations and student capabilities. Instructors often want students to be able to reason independently, to make interpretations and to draw on basic quantitative concepts in their courses; they seem less concerned about student recall of specific techniques. Students, on the other hand, are more successful with routine, standard computational tasks and often show less ability to use conceptual knowledge or insight to solve less standard quantitative problems (Bauman and Martin, to appear). Several problems will illustrate these findings and the nature of our tests.

Instructors of courses that have a calculus prerequisite often want students to understand what a derivative represents; they are usually not interested in student recall of differentiation techniques or formal limit definitions. Two problems designed to probe student understanding of derivates have been chosen by instructors for use in many courses.

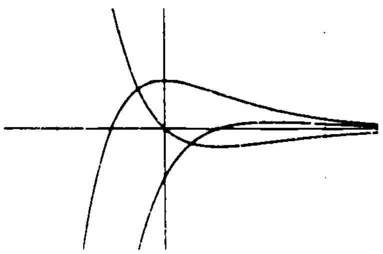

Figure 1.

Problem 1 *Figure 1 gives the graphs of a function, f, and its first and second derivatives, f′ and f″. Label each curve as the function or its first or second derivative. Explain your answers.*

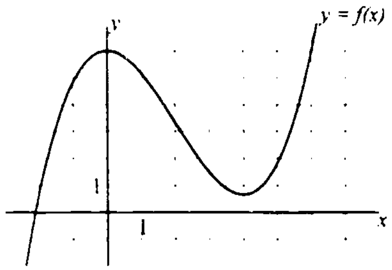

Figure 2.

Problem 2 *Figure 2 gives the graph of a function* $y = f(x)$. *Use the graph to answer these questions:*

(a) *Estimate* $f'(4)$ (84% correct)
(b) *Estimate* $f'(2)$. (44% correct)
(c) *On which interval(s), if any, does it appear that* $f'(x) < 0$? (65% correct)

(The percentages are the proportion of students in a recently assessed engineering course who answered the question correctly—the course prerequisite was three semesters of calculus)

Few students with only one semester of calculus have answered either problem correctly on our tests, although the material is drawn from the early part of first semester calculus. Even in classes where students have completed the regular three-semester calculus sequence their success rates are surprisingly low for these introductory problems. For example, about three-quarters of the students in on class correctly labeled the three curves in problem 1; under one-third of those students could adequately justify their labeling. The students had reasonable mathematics backgrounds: More than half had a B or better in their previous mathematics course, which was either third semester calculus or linear algebra. Just five of the 87 students had a D or F for their previous mathematics course. Success rates are higher if we just ask them to differentiate or integrate a function. For example, in the same class over tee-quarters of the students correctly evaluated $\int_0^2 te^{-t}\,dt$.

These results provide useful information about both (a) faculty expectations in other departments (and in upper level mathematics courses assessed as part of the program) and (b) student capabilities in relation to those expectations and various mathematical backgrounds. We have found that most junior level courses have one of three kinds of expected backgrounds: (a) no college mathematics, (b) one semester of calculus and perhaps a first statistics course, and (c) the full three-semester calculus sequence with some work in differential equations. Although the first level of expectations does not require collegiate mathematics, many instructors do expect a certain level of quantitative literacy from school mathematics and statistics.

The purpose of this paper is not to report our findings, some of which have been reported elsewhere (Bauman and Martin, to appear). Individual findings, such as those given above, have local significance, but we have no reason to believe they are generalizable beyond specific courses or perhaps our own institution. The significance of this work for others lies in the methodology for investigating the match between faculty expectations and student capabilities. Because each assessment is closely tied to a specific course, the assessment's impact is often narrowly focused. Surprisingly, though, some findings have even had a campus wide effect on the undergraduate curriculum.

Impact of the Assessment Project

A question about this, in fact any, assessment program is What is its impact? How can this make a difference and lead to improvement? After all, it is well known that students have difficulties with quantitative skills and reasoning. How does assessment guide us in the future? Such questions come from a view of assessment as summative, evaluative, and judgmental: something external that occurs at the end, that points to success or failure. It is a top down view, with assessors making the judgements and being responsible for recommending changes. Our view of assessment is different. Our work has had an impact, but in a broader sense than suggested by the forgoing questions.

The model for this project comes from a conception of assessment as an integral, ongoing part of education that has *formative* and *summative* characteristics. It is based on the idea that faculty members are best able to respond to information about student capabilities; what they might need is assistance identifying their own expectations and the relevant knowledge and skills of their students. This form of assessment is designed to have an impact by promoting reflection and by encouraging curricular and pedagogical decision-making based on knowledge rather than on assumptions and intuition.

It is worth noting that recent mathematics education research in elementary grades has shown that teacher knowledge is an important distinguishing characteristic of the type of learning that occurs in classrooms. Content knowledge and pedagogical content knowledge are important, but perhaps most significant for college faculty is the idea that effective teachers have a good sense of what their students know and use this knowledge to guide their instruction (see Fennema and Franke, 1992 for a discussion of the impact of teachers' knowledge). Assessment should help faculty to be attuned to the knowledge and capabilities of their students in relation to the demands of their course, thereby fostering instructional improvement.

Impact at a variety of levels. Instructors have mostly reacted very favorably to the assessment process. Those who do not report making any changes either found from the tests that students had the prerequisite skills or said that they were already aware of the difficulties and had modified their approach to deal with them—the project simply confirmed what they had suspected. In cases where instructor expectations differed from the results they often reported making changes, either by omitting reviews that no longer appeared necessary or by including additional work to develop important, missing capabilities.

Students report less influence of assessment, partly because many mistakenly see it as a pretest of material that will be studied in the course. Others fail to see the connection between a mathematical problem on the test and the way the concept is used in the course. For example, the test may include an item involving the concept of definite integral as area under a curve—in the course, students may use the concept in their work with frequency distributions without recognizing the connection to the test problem. In technical courses, many students (perhaps around half the class) reported studying both before and after the assessment test and said that the review was useful. Sometimes, unfortunately, students made comments on our follow-up questionnaires such as "Waste of my time" or "If I wanted to be a math major I would have taken a math course." Most students, when questioned at the end of the semester, recognized that the skills were important in their course but had not chosen to use assessment information to help prepare for those requirements. Students in more technical courses are more likely to make comments such as "Helped to shock me into relearning some calculus" and "The written corrections—including specific reasons why I did not reach the correct answer—were greatly appreciated!" Such reactions show that some students do, in fact, find the diagnostic exercise useful.

Departmental impact. The value to the Department of Mathematics of the data generated by assessment is quite clear. We report annually to the entire faculty, but we have probably had greater curricular influence by targeting our findings at individuals and committees responsible for specific levels or groups of courses, particularly precalculus and calculus. Findings from many assessed courses have shown, for instance, that faculty want students to interpret graphical representations. This had not always been emphasized in mathematics courses. It was somewhat ironic, but instructive, that in an early meeting to discuss our findings with a curriculum group in mathematics one faculty member remarked about a problem 2, "I'm not surprised students couldn't do that · I never ask such questions in my class." A colleague immediately responded that he thought such tasks were very important and always emphasized such ideas when he taught calculus. Obviously our assessment work can stimulate valuable discussions about what is and should be covered in undergraduate mathematics courses.

Our findings about graphical representations have led course coordinators to encourage instructors to give increased attention to graphical representations of functions. Perhaps more important, though, is what our work shows about the kind of mathematical skills needed in other departments: Those instructors seem less concerned about computational, algorithmic knowledge than more conceptual, problem-solving capabilities. This has implications not just for the *content* of mathematics courses, but also for the *way* that mathematics is taught including expectations for what students should *do*.

Assessment has influenced participating departments. To help ensure that assessment results are seen and discussed beyond the individual course, we produce a summary report for faculty members in participating departments. After distributing this written report, members of the assessment committee attend a regular faculty meeting to ans er questions and discuss the issues raised by assessment. The information we provide could lead to a variety of departmental changes (so, not all quantitative problems are the responsibility of the mathematics or statistics departments). Several examples will highlight the impact of our work has had on other departments.

- After finding that many students in an introductory course were unable to handle material from calculus, one department increased the prerequisite from first semester business calculus to two semesters of the regular calculus sequence. They did this not because the students needed the additional content, but to ensure that their students had further developed the necessary fundamental ideas by using and reviewing them in later mathematical work.
- In another department, many students had poor records for their college mathematics courses. During the faculty meeting at which assessment outcomes were discussed, a faculty member remarked that students claimed they did not realize they would be expected to know material from a prerequisite calculus course in their later course work. One response to this problem involves student advising, especially for first- and second-year students as they meet general education requirements. Faculty advisors should emphasize that prerequisite courses cover important knowledge that will be essential later; that prerequisites are not just additional credits that serve as a hurdle on their path to the degree.
- Faculty members in other departments typically welcome the interest of our committee, with its mathematics and statistics faculty members, in their quantitative expectations of students. Often, they say that this is an important area that they have neglected in the past. Recently, one (non technical) department included discussions of quantitative difficulties of their students as they restructured their undergraduate program, deciding to incorporate more quantitative reasoning work in their own lower level courses.
- In another department, following a planning session with our group for an upcoming assessment, the coordinator for a large introductory science course remarked that he "couldn't remember having spent even five minutes discussing the specific quantitative needs of students with colleagues" during his years (decades) at the university (the course had a calculus prerequisite). We were gratified that the faculty members we were working with recognized one of our program's most important goals and the value of this form of asssessment.

Campus-wide impact of assessment. An early, striking finding from the assessment project was that some students were actively avoiding any courses with quantitative expectations. These students were unable to complete basic quantitative literacy tasks such as using percentages and extracting information from tables and bar graphs. A university curriculum committee saw these results and later recommended that all baccalaureate degree programs include a six-credit quantitative requirement (before this, it was possible to get a B. A. without any collegiate mathematics or statistics). The recommendation was adopted by the Faculty Senate, a clear indication that our focus on individual courses can produce information useful at the broadest institutional levels.

Faculty responses to assessment. How do faculty respond when many students do not have necessary skills, quantitative or otherwise? Sometimes, we have found, with resignation: "It would be lovely if we required three or even two semesters of calculus. But one will have to do," was the response from one instructor, articulating the constraints that apply to prerequisites in degree programs. Another faculty member said he had chosen to leave quantitative material completely out of his non technical course because (a) students lacked the necessary skills and (b) he had plenty of other material to cover. This was just the most extreme reaction that we have encountered to the problem of students lacking quantitative capabilities. Other faculty members have also reported "watering down" quantitative expectations in courses because of perceived student weaknesses. This is a disturbing finding, and one that cannot be easily addressed by individuals since students can "opt out" of courses with high expectations. Our assessment can help to stem this trend by exposing the institutional impact of such individual decisions to faculty members and departments. Some faculty carry on regardless. One professor remarked that "The students pick up [the necessary skills] as we go, drop, or perish," articulating another response to apparent weaknesses.

Shortcomings of this assessment work. Angelo and Cross (1993), in their practical classroom assessment guide for college faculty, suggest that assessment is a cyclic process with three main stages: (a) planning, (b) implementing, and (c) responding (p. 34). Their view of assessment as on ongoing, integrated part of instruction is similar to that of our project. Although I have cited several positive responses to our assessment work, there have also been instances where assessment revealed problems but no action was taken. This breaks the assessment cycle after the second stage. I expect this to be an enduring problem for several reasons.

- Our approach is deliberately collaborative and non prescriptive. Because of this, faculty participate willingly—assessment is voluntary for individuals because its utility depends on participants believing it is worthwhile. Our primary role is as information providers; we help faculty members to identify expectations and provide information about student capabilities and backgrounds. Interpretation of and response to these findings is left to those who are affected (we do, of course, respond to requests for suggestions or interpretations).
- Not all problems have simple solutions. If students have difficulty with the arithmetic of complex numbers or reading graphs, the problem can be addressed by including material in mathematics courses. When assessment shows that students have difficulty with concepts, the remedies are much less obvious. Including some new problems or even a unit will probably not be the answer. Still, one can hope that faculty awareness of student difficulties of deeper and more complex origins may increase attention given to the needs and capabilities of students in individual classrooms.
- Solutions to some problems do not rest with the institution. For example, a department offered an introductory course that required a semester of calculus. We assessed in the course for several years, finding that most students were unable to handle any tasks from calculus. Each year, as we revised the assessment tests the instructor removed more of the calculus material, reflecting his growing awareness of student capabilities. We knew that many students had taken a business calculus course instead of the more rigorous science and engineering version, so we suspected that business calculus was not adequately covering the necessary material. Our view changed dramatically during the third assessment, when we also gained information about the students' backgrounds in mathematics. Many students had very poor records in mathematics: some had repeated mathematics courses two or three times and many had low grades (C or D) in calculus. This information explained why they had so much trouble with calculus a year or two later. The real solution was for students to work harder to do better in prerequisite courses.

We recognize that assessment is cyclic and that responding to findings, especially of shortcomings, is important; we also know that not every problem has a solution. Faculty members are able to deal with the educational issues. They can do this effectively if they have information about the existing educational situation.

Conclusion

Assessment has always had a prominent, if narrow, role in the study of mathematics in colleges and universities. Except for graduate qualifying examinations, most of this attention has been at the level of individual courses, with assessment used to monitor student learning during and at the end of a particular class. The natural focus of a mathematics faculty is on their majors and graduate students. Still, their role in a college or university is much larger because of the service they provide by training students for the quantitative demands of other client departments. It is important that mathematicians monitor the impact of this service role along with their programs for majors.

This paper outlined a locally developed procedure that addresses an important but often neglected dimension of assessment in mathematics: student retention of mathematical knowledge over the longer term and the match between faculty expectations and student capabilities in subsequent courses. Recently, Selden and Selden (1993) listed long term retention of mathematical knowledge as one of several important issues deserving study. Although this sort of assessment has received little attention in the past, it is especially worth pursuing in this era of reform in school and collegiate mathematics. Naturally, quantitative assessment also contributes to assessment at the broader institutional level, a need that has received increasing attention in recent years (Ewell, 1991). Mathematics faculties have an interest in assessing their work rather than leaving it to outsiders with less stake or interest in the subject. The approach reported here allows mathematics departments and faculty to give more attention to this important aspect of their educational mission.

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