Tensions and Tethers: Assessing Learning in Undergraduate Mathematics

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In 2001, after a decade of encouraging and supporting comprehensive assessment of learning in undergraduate mathematics, the Mathematical Association of America (MAA) was well positioned to seize an opportunity for funding from the National Science Foundation (NSF) to intensify and extend this support. As a result, NSF awarded MAA a half-million dollars for a three-year project "Supporting Assessment in Undergraduate Mathematics" (SAUM) that provided a much-needed stimulus for assessment at the departmental level. The need for such a program is rooted in the various and often conflicting views of assessment stemming from worry about uses of the results, difficulties and complexities of the work, and possible conflicts with traditional practices. Faculty navigating through these views to develop effective assessment programs encounter numerous tensions between alternative routes and limiting tethers that restrict options. Against this background the MAA launched SAUM in January 2002.

The goal of SAUM was to encourage and support faculty in designing and implementing effective programs of assessment of student learning in some curricular block of undergraduate mathematics. SAUM leaders were reasonably sure that many faculty would welcome help with assessment because many colleges and universities were under mandates to develop and implement programs to assess student learning—mandates originating in most cases from external entities such as regional accrediting bodies. Our expectations were accurate. We found many faculty willing to tackle assessment but unenthusiastic and even skeptical about the work.

During the three years of SAUM we promoted assessment to hundreds of faculty in professional forums and worked directly with 68 teams of one to five faculty from 66 colleges or universities in SAUM workshops. The final SAUM workshop—restricted to assessing learning in the major—will conclude in January 2006. Most of the 68 teams had two or three members, with two usually attending the workshop sessions. As these teams worked at the face-to-face workshop sessions, as they continued their work back home, and as we promoted assessment to the larger audiences in professional forums, skepticism was evident in lack of enthusiasm and inevitably brought forth arguments against assessment as we were advocating it.

The arguments were basically of two types: tensions and tethers. Tensions are forces that mitigate against meaningful and effective assessment, pulling toward easier and less effective models. A common example is the tension between doing assessment that is effective in plumbing the depths of student understanding and doing assessment that is practical and more superficial. Most tethers are ties to

past and present practices that are likely to continue and possibly prevent or restrict developing effective assessment. For example, many instructional programs are tied to traditional in-course testing and have no plans to change, placing significant limits on assessment.

Below, I describe some of these assessment tensions and tethers, along with some ways SAUM tried to ease the tensions and untie the tethers. First, however, I will explore SAUM retrospectively and describe how it evolved from a decade of assessment activity by the MAA. The paper concludes with a more detailed description of SAUM.

From Awareness to Ownership

The SAUM proposal to NSF was based on an unarticulated progression of steps necessary to get college and university faculty fully committed to meaningful and effective assessment of student learning. The first step is *awareness*, the second, *acceptance*; next comes *engagement*, and finally *ownership*.

First, we aimed to make faculty *aware* of the nature and value of assessment by stimulating thought and discussion. Second, we encouraged *acceptance* through knowledgeable and respected plenary speakers at workshops, and collegial interaction with others interested in and sometimes experienced in assessment. Examples of the plenary presentations, documented on the SAUM website,[1] are presentations and writings by Lynn Steen (SAUM senior personnel) and Peter Ewell (SAUM evaluator). Their combined overview of how assessment is positioned in the larger arena of Federal, state, and university policies and practices can be surmised from their article *The Four A's: Accountability, Accreditation, Assessment, and Articulation* (Ewell & Steen, 2003). This article is based on a presentation by Peter Ewell at the face-to-face session of Workshops #1 and #2 at Towson University in January 2003.

Peter Ewell was an unexpected and valuable resource at workshops, giving plenary presentations and generously agreeing to consult with individual teams. His broad historical perspective, vast experience in consulting with and advising colleges and universities, and intimate knowledge of policies of accrediting bodies gave teams both encouragement and helpful advice. Further, Peter's view as a non-mathematician was helpful both for his questioning and his knowledge of other disciplines. Peter's expertise was nicely complemented by Lynn Steen's wide experience with mathematics, mathematics education, and mathematics and science policy issues.

[1] www.maa.org/saum

Third, we urged workshop participants to *engage* in designing and implementing an assessment program at their home institutons. Face-to-face workshop sessions required exit tickets that were plans for actions until the next face-to-face session. Teams presented these plans to their workshop colleagues and then reported at the next session on what had been done. As noted by Peter Ewell in his evaluator's report (pp. 19–26), this strategy provided strong incentive for participants to make progress at their own institution so that they would have something to report at the next session of the workshop.

Finally, we promoted *ownership* by requiring that each team write a case study describing its assessment program or present a paper or poster at a professional meeting. As of this writing, the teams have produced 24 case studies, 24 paper presentations, and 18 posters. Paper sessions were sponsored by SAUM at MathFest 2003 in Boulder, Colorado, and at the 2004 Joint Mathematics Meetings in Phoenix, Arizona. SAUM also sponsored a poster session at Phoenix. Finally, an invited paper session is scheduled for the 2006 Joint Mathematics Meetings in San Antonio, Texas.

Background for SAUM

SAUM's background goes back to an MAA long-range planning meeting in the late 1980s. At that meeting I asked what the MAA was going to do regarding the growing movement on assessment that had entered the US higher education scene about a decade earlier. Indicative of the fact that no plans had been made by MAA, I soon found myself as chair of the 12-member Subcommittee on Assessment of MAA's Committee on the Undergraduate Program in Mathematics (CUPM). We were charged with advising MAA members on policies and procedures for assessment of learning in the undergraduate major for the purpose of program improvement. Very few of the subcommittee members had any experience in or knowledge of the kind of assessment we would eventually understand that we needed, and we struggled with the multiple meanings and connotations of the vocabulary surrounding the assessment movement. Nevertheless, we plowed into our work at the summer meeting in Columbus, Ohio, in 1990.

In retrospect, our work developed in three distinct phases: (1) understanding the assessment landscape that included outspoken opposition to assessment; (2) developing guidelines for assessment; and (3) compiling case studies of assessment programs in mathematics departments. A fourth phase, seen in retrospect, was the extensive faculty awareness and professional development made possible by SAUM.

Two vehicles proved very helpful in Phase 1. First, in 1991, I moderated an e-mail discussion on assessment

among fourteen academics (twelve mathematicians and two non-mathematicians) that included four members of the Assessment Subcommittee. Some of the discussants were opposed to assessment as it was then evolving; their worries ranged from operational issues like extra work to fundamental issues like academic freedom. E-mail was neither user-friendly nor regularly read in 1991, and managing the information flow and compiling it into a coherent report was quite challenging. Nonetheless, a report was written and published in *Heeding the Call for Change* (Madison, 1992), edited by Lynn Steen, who had been both helpful and encouraging on my involvement with assessment.

Appended to the report of the 1991 e-mail discussion is a reprint of a seminal article by Grant Wiggins consisting of the text of his 1990 keynote address to the assessment conference of the American Association for Higher Education (Wiggins, 1992). This annual conference began in 1985 and over the past two decades has been the premier convening event on assessment in higher education. Between 1990 and 1995, I attended these conferences, learned about assessment outside mathematics, and eventually mastered the language. Plenary speakers such as Wiggins, Patricia Cross, and Peter Ewell were impressive in their articulate command of such a large academic landscape.

Phase 2 of the work of the Assessment Subcommittee consisted of producing a document on assessment that would both encourage assessment and guide department faculties in their efforts to design and implement assessment programs. Grounded largely in the e-mail discussion and a couple of AAHE assessment conferences, I forged a first draft of guidelines that was based on assessment as a cycle that eventually would have five stages before it repeated. By 1993 the Subcommittee had a draft ready to circulate for comment. Aside from being viewed as simplistic by some because of inattention to research on learning, the guidelines were well received and CUPM approved them in January 1995 (CUPM, 1995).

Further plans of the Subcommittee included gathering case studies as examples to guide others in developing assessment programs. The small number of contributions to two contributed paper sessions that the Subcommittee had sponsored did not bode well for collecting case studies, especially on assessment of learning in the major. However, strong interest and enrollment in mini-courses on assessment indicated that case studies might soon be available. One of the Subcommittee members, William Marion, had expressed interest in teaming up with Bonnie Gold and Sandra Keith to gather and edit case studies on more general assessment of learning in undergraduate mathematics. By agreeing to help these three, I saw the work of the Subcommittee as essentially finished and recommended that we be discharged. The Subcommittee was dissolved, and in 1999 Assessment Practices in Undergraduate Mathematics containing seventy-two case studies was published as MAA Notes No. 49, with Gold, Keith, and Marion as editors (Gold, et al., 1999).

Two years later, in 2001, NSF announced the first solicitation of proposals in the new Assessment of Student Achievement program. During two weeks in May 2001 while I was serving as Visiting Mathematician at MAA, with help and encouragement from Thomas Rishel, and with the encouragement and advice from members of CUPM, most notably William Haver, I wrote the proposal for SAUM. I was fortunate to gather together a team for SAUM that included the principals in MAA's decade of work on assessment: Bonnie Gold, Sandra Keith, William Marion, Lynn Steen, and myself. Good fortune continued when William Haver agreed to direct the SAUM workshops and Peter Ewell agreed to serve as SAUM's evaluator.

In August 2001 I learned that the NSF was likely to fund SAUM for the requested period, January 1, 2002, to December 31, 2004, at the requested budget of $500,000, including a sub-award to the University of Arkansas to fund my role as project director. Because we were reasonably sure of an award, we were able to begin work early and in effect extend the period of the project by several months. The award was made official (DUE 0127694) in fall 2001.

The 1995 CUPM Guidelines on Assessment are reprinted as an appendix to *Assessment Practices in Undergraduate Mathematics* (CUPM, 1995) and an account of MAA's work on assessment is in the foreword (Madison, 1999). Another lighter account of my views on encountering and understanding assessment, "Assessment: The Burden of a Name," can be found on the website of Project Kaleidoscope (Madison, 2002).

Tensions and Tethers

As noted above, throughout SAUM and the MAA's assessment work that preceded SAUM, various tensions and tethers slowed progress and prompted long discussions, some of which were helpful. Some faculty teams were able to ease or circumvent the tensions while others still struggle with the opposing forces. Likewise, some were able to free their program of the restraints of certain tethers, while others developed programs within the range allowed.

A major obstacle to negotiating these tensions and tethers is the lack of documented success stories for assessment programs. Very few programs have gone through the assessment cycle multiple times and used the results to make

changes that result in increased student learning. This absence of success stories requires that faculty work on assessment be based on either faith or a sense of duty to satisfy a mandate. In theory, the assessment cycle makes sense, but implementation is fraught with possibilities for difficulties and minimal returns. There is, thus, considerable appeal to yield to tensions—to do less work or to work only within the bounds determined by a tether to traditional practice.

Easing Tensions

The most prominent tension in assessment is *between what is practical and what is effective* in judging student performance and understanding. There are several reasons for this, some of which involve other tensions. Multiple-choice, machine-scored tests are practical but not effective in probing the edges and depths of student understanding or for displaying thought processes or misconceptions. Student interviews and open-ended free-response items appear to be more effective in this probing, but are not practical with large numbers of students. We know too little about what is effective and what the practical methods measure, but we believe that getting students to "think aloud" is revealing of how they learn. Unable to see evidence of value in the hard work of effective assessment, we very often rely on the results of practical methods—believing that we are measuring similar or highly correlated constructs.

To ease this tension between the practical and the "impractical," we recommended that faculty start small and grow effective methods slowly. Interviewing a representative sample of students is revealing; comparing the results of these interviews with the results of practical methods can provide valuable information. Knowing how students learn can inform assessment in an essential and powerful way. We know too little about how mathematical concepts are learned, especially in a developmental fashion, and we know too little about how assessment influences instruction. This is both an impediment to doing assessment and a challenging reason for doing so. One can use it as an excuse for waiting until we know more about learning, or one can move ahead guided by experience but alert to evidence of how learning is occurring and how learning and assessment are interconnected.

Many assessment programs are the result of requirements by accrediting agencies or associations. Often these requirements boil down to applying three or four tools to measure student learning outcomes for majors and for general education. For example, the tools for a major could be a capstone course, exit interviews, and an end-of-program comprehensive examination. Consequently, discipline faculties can meet the requirements by doing minimal work—designating a capstone course, interviewing graduating seniors, and selecting an off-the-shelf major field achievement test—and getting minimal benefits. Reflecting on the results of the assessment and considering responses such as program or advising changes requires more work and raises questions about past practices. This tension *between getting by with minimal work for minimal payoff and probing deeply to expose possibly intractable problems* does offer pause to faculty whose time is easily allocated to other valued work.

The tension pulling toward meeting mandated assessment requirements minimally is reinforced by the bad reputation that assessment has among faculties. This reputation derives both from worries about uses of assessment results for accountability decisions and from numerous reports of badly designed and poorly implemented large-scale high stakes assessments. Unfortunately, few people understand the broad assessment landscape well enough to help faculty understand that their assessment work has educational value that is largely independent of the public issues that are often used to discredit assessment. Fortunately, in SAUM we did have people who understood this landscape and could communicate it to mathematics faculty.

Mathematicians are confident of their disciplinary knowledge and generally agree on the validity of research results. However, their research paradigm of reasoning logically from a set of axioms and prior research results is not the empirical methodology of educational practice where assessment resides. This tension *between ways of knowing* in very different disciplines often generates disagreements that prompt further evidence gathering and caution in drawing inferences from assessment evidence. Eventually, though, decisions have to be made without airtight proof.

This tension is amplified by the complexity of the whole assessment landscape. For example, the so-called three pillars of assessment—observation, interpretation, and cognition—encompass whole disciplines such as psychometrics and learning theory (NRC, 2001).

Assessment of learning in a coherent block of courses often provides information that can be used to compare learning in individual courses or in sections of a single course, and hence to judge course and instructor effectiveness. Such comparisons and judgments create tension *between individual faculty member's academic freedom and the larger interest of programs.* Indeed, learning goals for a block of courses do place restrictions on the content of courses within the block.

Mathematics faculty members are accustomed to formulating learning goals in terms of mathematical knowledge

rather than in terms of student performance in using mathematics. This creates tension *between testing what students know and testing for what students can do.* Since judging student performance is usually far more complex than testing for specific content knowledge, this tension is closely related to that between practical versus effective tension discussed above.

Partly because of the nature of mathematical knowledge, many instructional programs have not gathered empirical evidence of what affects student learning. Rather, anecdotal information—often based on many years of experience with hundreds of students—holds sway, indicative of the tension *between a culture of evidence and a culture of anecdotal experience.* Since empirical evidence is often inconclusive, intuition and experience will be valuable, even more so when bolstered by evidence.

Untying Tethers

Mathematics programs in colleges and universities are very tradition-bound, and many of these traditions work against effective assessment of student learning. Sometimes, these tethers can be untied or loosened; sometimes they cannot. The tethers we encountered in SAUM include:

- Tethers to traditional *practices in program evaluations.* We are accustomed to evaluating programs by the quantity of resources attracted to the program—inputs—as opposed to quality of learning outcomes. One reason for this traditional practice is the lack of evidence about learning outcomes, or even an articulation of what they are.
- Tethers to traditional *faculty rewards system*. Traditionally, mathematics faculty rewards are based on accomplishments that do not include educational or empirical research results much less amorphous scholarship on assessment. Even if scholarship on assessment is recognized and rewarded, the outlets for such work are very limited. Unlike the situation in mathematics research, standards for judging empirical assessment work are not widely agreed to and, consequently, are inconsistent.
- Tethers to traditional *in-course testing.* This tether was very apparent in the work of SAUM workshop teams. Going beyond assessing learning in a single course to assessing learning in a block of courses was a major step for many faculty teams. This step involved a range of issues from developing learning goals for the block to logistical arrangements of when and where to test. Even when learning goals were agreed to, assessing areas such as general education or quantitative literacy offered special challenges. Recognizing this tether, Grant Wiggins has compared assessment of quantitative literacy to performance of sports. One can practice and even master all the individual skills of basketball, but the assessment of basketball players is based on performances in actual games. Wiggins concludes that assessment for quantitative literacy threatens all mainstream testing and grading in all disciplines, especially mathematics (Wiggins, 2003).
- Tethers to traditional *lecture-style teaching.* Especially with large classes, lecture-style teaching severely limits assessment options, especially for formative assessment. Some electronic feedback systems allow lecturers to receive information quickly about student understanding of concepts, but probing for the edges of understanding or for misconceptions requires some other scheme such as interviewing a sample of the students.
- Tethers to a traditional *curriculum.* The traditional college mathematics curriculum is based largely in content, so assessment of learning (including learning goals) has been couched in terms of this content. Standardized testing has centered on this content. Students and faculty expect assessment items to address knowledge of this content. Consequently, there is resistance to less specific assessment items, for example, open-ended ill-posed questions.

Components of SAUM

SAUM had five components that were aimed at encouraging faculty to design, develop, and implement meaningful assessment programs. The plan, as outlined earlier, was to move faculty in departments of mathematics from awareness of assessment, to acceptance, to engagement, and finally to ownership.

Component 1. The initial component was aimed at stimulating thought and discussion, thereby raising awareness about assessment and why it could be a valuable part of an instructional program. There were three principal vehicles:

- Panels at national and regional professional meetings.
- Ninety-minute forums at meetings of MAA Sections. Forums were held at seventeen of the twenty-nine sections.
- Distributing the 1999 MAA Notes volume, *Assessment Practices in Undergraduate Mathematics* (Gold *et al*. 1999). At the beginning of the SAUM project a copy of this volume (containing seventy-two case studies) was mailed to the chair of each of the 3000 plus departments of mathematics in two-year and four-year colleges or universities in the United States.

Component 2. The second component involved expanding and updating case studies in *Assessment Practices in Undergraduate Mathematics* and gathering new case studies as the main contents of a new volume. For reasons that are unclear, few of the original case studies were updated. The project had more success in gathering new case studies, mainly because the workshops provided natural vehicles for generating them. Those case studies along with supplementary essays and syntheses constitute the contents of this present volume.

SAUM originally planned to support six areas of assessment:

- The major: Courses in the undergraduate mathematics major, including those for prospective secondary school mathematics teachers.
- General education or quantitative literacy: General education courses in mathematics and statistics, including those aimed at achieving quantitative literacy.
- Mathematics for teachers: Blocks of mathematics courses for prospective elementary or middle school teachers.
- Placement programs or developmental mathematics: School mathematics as preparation for college work.
- Reform courses or other innovations.
- Classroom assessment of learning.

As SAUM developed and workshop teams enrolled, this original list of six areas evolved into five: the major, general education, mathematics for teachers, pre-calculus mathematics, and mathematics in mathematics-intensive majors. Well over half of the sixty-eight SAUM teams worked in just one of these areas—assessment of the major.

Component 3. Development and delivery of the four faculty development workshops plus a self-paced online workshop was the central component of SAUM. As noted above, the workshop teams provided almost all the new case studies and provided a critical audience for selecting resources to support assessment. William Haver was the principal organizer and designer of the SAUM workshops. (He also served as a member of his university's team in the first workshop.)

Preliminary evidence indicates that the four workshops were successful in moving the faculty teams to engagement with assessment and many to ownership. We do not have evidence about the effectiveness of the online workshop. Although the suggested readings in the online workshop are selected to move faculty through the awareness, acceptance, engagement, and ownership sequence, face-to-face support and collegial interaction may be an essential ingredient that is missing from the online approach. Workshop participants repeatedly told us that the interaction among teams was important, and we relied heavily on this feature to move participants from acceptance to engagement and ownership. Knowledge and experience of workshop leaders and presenters seemed to work for awareness and acceptance but not much further.

Although not specified as a goal in the original SAUM proposal, one significant accomplishment of SAUM was identifying and developing leadership in assessment of learning in undergraduate mathematics. SAUM began with six leaders, none of whom claimed broad expertise in assessment or in conducting workshops for faculty on assessment. Since each workshop session would require four or more leaders or consultants, recruiting new leaders seemed essential. We were fortunate that in the first and second workshops several leaders emerged. From these leaders we recruited Rick Vaughn (Paradise Valley Community College), William Martin (North Dakota State University), Laurie Hopkins (Columbia College), Kathy Safford-Ramus (St. Peter's College), and Dick Jardine (Keene State College). These new leaders provided experience in assessment at various levels at a variety of institutions and enriched our subsequent workshop sessions by sharing their experiences and consulting with teams on developing assessment programs. Two of the five—Laurie Hopkins and Dick Jardine, both from the second workshop—assisted with editing of the case studies.

Component 4. Construction of the SAUM website began at the outset of the project. The site, a part of MAA Online[2] has several major components that supported SAUM and continue to provide resources for assessment across the US. These components include:

- An annotated bibliography on assessment drawn from multiple sources. Entries are grouped into four areas: (i) Assessment Web Sites; (ii) Policy and Philosophy in Mathematics Assessment; (iii) Case Studies in Mathematics Assessment; and (iv) Policy and Best Practices in Postsecondary Assessment.
- A communication center for SAUM workshops, sessions at national meetings, and section forums.
- Links to seventy-three sites that have information on assessment relevant to the activities of SAUM.
- A frequently asked questions (FAQ) section containing brief answers to 32 common questions about assessment.
- Online copies of case studies and other papers that were published in *Assessment Practices in Undergraduate Mathematics* (Gold, 1999).

[2] www.maa.org/saum

- Postings of new case studies including exhibits and supporting documents. Many of these exhibits and documents will not appear in the print, but will reside on the site to be used as supplements to the printed cases.
- The online assessment workshop.
- The contents of this present volume, upon publication.

Component 5. Dissemination of SAUM employs three media: print (publications and mailing), electronic (development and maintenance of a web site), and personal (presentations at national meetings).

- The SAUM report (this volume) will be offered to over 3000 US mathematics departments in two-year and four-year institutions.
- An extensive overview of the SAUM report will appear as a special supplement in FOCUS.
- The SAUM web site will include the contents of this SAUM report, as well as the several items listed above.
- Presentations at national meetings have so far included 24 contributed papers and 18 poster exhibits at MathFest 2003 and the Joint Mathematics Meetings in January 2004.

Beyond SAUM

Through the SAUM workshops, nearly 200 mathematics faculty members participated in the development and implementation of programs of assessment in 66 college and university mathematics departments. In addition, several hundred other faculty became more aware of the challenges and benefits of assessment through other SAUM activities. The SAUM web site and this volume constitute valuable resources for others interested in assessment.

Nonetheless, the accomplishments of SAUM are probably insufficient to provide a critical mass of experience and understanding to cause assessment to become a natural part of instructional programs in all mathematics departments. Because assessment is largely alien to beliefs of many mathematics faculty and to traditions in most mathematics departments, further work by the community will be needed to overcome the tensions and untie the tethers discussed here. Increased calls for accountability for student learning will keep faculty interested but unenthusiastic about assessment. Only success stories that are documented to the satisfaction of skeptical mathematicians will break through the tacit resistance and cause faculty to take ownership of and work diligently on assessment programs. Perhaps some of the SAUM-inspired programs will provide these stories.

If faculty understood the potential benefits of assessment in increased student learning and how to assess for this learning, projects like SAUM or an MAA Subcommittee on Assessment should not be necessary. But the chance of this happening is slim. Some three decades ago the MAA's Committee on Placement Examinations anticipated eliminating the need for the MAA Placement Testing Program by educating faculty about placement. The Placement Testing Program was finally discontinued about five years ago—not because it was no longer needed but because the difficulties and complexities of such a program were beyond the MAA's scope of operation. After decades of support from a national program, faculty continue to ask for guidance on placement testing, so MAA is now looking for ways to meet this need. Assessment is much broader and less well defined than placement testing, so support from MAA for assessment in undergraduate mathematics will likely be needed for years to come.

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