

Calculus Assessment (Revised-March 2001)

1 Introduction

A major item in the strategic planning process of the Math Department at UW is to provide excellent education in our calculus courses. These courses are taken by students heading into a wide variety of majors and are foundational to many disciplines in the physical, mathematical, biological, and social sciences.

Providing excellent courses is an ongoing process of continual change and revision. Through a Tools for Transformation grant, the Math Department has an opportunity to make a substantial revision in the presentation of our main calculus sequence, Math 124/125/126. The changes being funded for three years (2001-2004) are patterned partly after changes that we made recently in Math 111/112 (Business Math/Calculus): smaller class size, more instructor-student contact, and more in-depth class work have positively changed the atmosphere of these courses; Cathy Beyer, Director of the UW SOUL project, has indicated that business and economics students are pleased with Math 111/112.

After the three-year Tools for Transformation grant expires, permanent funding for these changes through the Office of the Dean of Arts and Sciences has been offered, provided that the changes made possible by this funding are deemed sufficiently successful to warrant their continuance.

This document sets out the objectives of the ongoing revision of the calculus sequences, proposes means of assessing the progress made toward these objectives, and suggests a process for the Dean of Arts and Sciences and the Math Department to use these means of assessment to evaluate the success of these changes.

The Office of Educational Assessment (OEA) and the Center for Instructional Development and Research (CIDR) have been very helpful in devising effective means of assessment, and both OEA and CIDR will continue to be involved in the assessment procedure, including the design of effective surveys and conducting interviews and classroom observations.

2 Objectives of ongoing revision of calculus sequences

Effective assessment requires first that we are clear on what we are trying to accomplish. We have assembled our objectives into four main groups.

2.1 Objective 1: Student learning

Calculus education in the university environment has a number of challenges. Students enter calculus with an expectation that calculus is similar to the mathematics they have seen before. This is only partly true. There are new concepts, like limits, that are foreign to their experience. Most students taking calculus will use it in other disciplines, and learning to make the connections between problems in applications and the mathematical tools to solve these problems has often not been emphasized in their previous education; yet these are precisely the skills they will need in their future courses in other departments. The desired outcome for students in calculus courses includes learning a number of different skills. Time spent teaching one set of skills means less time spent teaching other skills. Ideally, all these skills would be mastered. A realistic objective is substantial progress in most of these skills, sufficient that students can proceed on to more advanced courses and use their calculus effectively in those courses. The skills we want to teach our students include the following.

A. Calculus skills

The ability to understand and do calculus within a standard mathematical framework.

B. Manipulative skills

Improved facility with prerequisite mathematics: algebra, trigonometry, analytic geometry.

(Mathematics is cumulative: one often learns the material in one course much better in subsequent courses when the current material is used extensively; calculus is often the time that students really master some of their earlier skills.)

C. Problem-solving skills

The ability to design solution outlines for multi-step and applied problems and thereby to solve these problems.

(“Story problems” or “word problems” are often feared and resisted by students. Yet, they provide an opportunity for students to apply their calculus skills as they learn them. Because of the cumulative nature of mathematics, this process of applying their calculus skills helps greatly in their mastering of these skills. In addition, they prepare students for solving the kinds of problems they will see in future classes that use calculus.)

D. Reasoning skills

The ability to reason rigorously.

(A major goal of much of university education, often labeled “critical thinking”, is

the ability of students to think at a level of sophistication appropriate to professionals in a given discipline. Although this ability can be highly discipline dependent, the rigorous reasoning skills necessary to do advanced mathematics transfer well to some important reasoning skills in many other disciplines, from sciences to humanities. Much of the subject matter of calculus, including in particular the more abstract and theoretical part, requires rigorous reasoning. Learning this subject matter helps develop reasoning skills. The objective here is that students advance their ability to reason logically as they are exposed to theoretical mathematical reasoning, and also as they learn new skills in calculus and improve their problem-solving skills.)

E. Vision of mathematics

Understanding the relevance of learning mathematics, and calculus in particular. (Students should learn enough about some applications of calculus that they can see the usefulness of calculus skills. In addition, as part of their learning in problem-solving skills, they should learn how to set up mathematical problems that arise from problems in applied fields. Problem-solving skills can be thought of as translation skills, translating applied problems into mathematical problems in order to solve them, and translating the mathematical solution into a meaningful answer to the applied problem. This goal of “vision” is one step beyond the problem-solving skills themselves. Reflecting upon what can be accomplished using calculus and problem-solving skills gives a different perspective on the value of mathematics, mathematical reasoning, and mathematical skills in contexts beyond the current calculus course.)

2.2 Objective 2: Student satisfaction and behavior

Learning a large amount of new material in a course can be exciting, but it can also be very difficult for students, both in the mechanics of learning and in the emotional response to the process and frustrations of learning. Calculus is a subject which, because of the combination of the challenging nature of the material and the importance of their performance to the future of students in many disciplines, often elicits strong responses from students. This is a built-in given in teaching calculus at the university level. Calculus courses should bridge the gap between students’ previous mathematical experience and the high-level demands of future courses.

There are a number of ways that the social aspects of teaching calculus can be managed, from a uniform and very disciplined experience to an entirely inductive, creative, and individual approach. What may work well for some students may not serve the larger student population as well.

This second objective is that the way in which we teach calculus offers students an

experience which can be satisfying to them as they experience it, and which they find to be an effective part of their educational experience at UW when they look back on it in the future.

The indicators of student satisfaction that we would like to observe include the following.

A. Satisfaction through successful learning

Probably the most important indicator of student satisfaction is successful learning. If the learning objectives described above are being met, students are getting the education which they came to UW to get.

B. Student involvement in class

Student attendance, student alertness in class, and student participation in class indicate that students perceive time spent in class as being useful to their learning.

C. Student initiative in course work

Students keeping up in the class, asking questions in class, and seeking help when they need it (e.g., coming to the Math Study Center) are also indicators that they perceive value in the course they are taking. Learning involves commitment from both instructor and students; when students make that commitment, it contributes to everyone's satisfaction in the experience. At the same time, when instructors offer an environment that encourages a high level of student commitment, that commitment indicates a level of student satisfaction in the course.

D. Alignment of instructor and student expectations

When students and instructors have agreement on the objectives of a course and the responsibilities of each person involved, generally the experience is positive. This alignment can be a serious challenge in calculus if either student or instructor expectations are way off base. Our objective here is to offer courses with reasonable instructor expectations, to make clear those expectations to students, and to work with students on aligning instructor and student expectations. It is our hope that closer contact between students and instructors and TAs in the smaller class environments proposed will lead to better alignment of expectations.

E. Satisfaction in student comments and evaluations

One indicator of student satisfaction is the comments they make concerning the course in a variety of contexts, including formal student evaluations.

2.3 Objective 3: Satisfaction of client departments

We want instructors in other departments in courses that our calculus students take subsequently to find that our students can use calculus effectively in these courses, and ultimately in their careers beyond UW.

2.4 Objective 4: Satisfaction of instructors

We want our instructors and TAs to be satisfied with the material being taught in the course, with student learning, and with student responses to the courses. This satisfaction continues to foster a positive atmosphere in the courses, which also aids in student satisfaction.

3 Changes in Math 124/125

Here is a summary of the major changes to be implemented in Math 124/125 to work toward improvement of these objectives. The changes listed here are those which involve extra funding. Other changes, including a change in textbook and reorganization of which topics are covered in which course, have also been made starting in Autumn 2000 after some test sections taught in the 1999-2000 academic year.

Our long term plan is to implement these changes first in Math 124/125. If they prove to be sufficiently successful, we would consider implementing them as well in Math 126 at a later date.

3.1 Smaller lecture size

Currently, Math 124 and 125 are taught in lecture sections of size 160. Lectures meet Monday/Wednesday/Friday for 50 minutes. The change would decrease the lecture size from 160 students down to 81 students.

3.2 Smaller quiz section size

The current quiz section size is 40. Each quiz sections meets twice a week, on Tuesday and Thursday for 50 minutes. Each lecture section has four quiz sections, taught by TAs. A typical arrangement would have two TAs associated with each lecture section, with each TA teaching two separate quiz sections of size 40 each (usually at back-to-back hours on Tuesday/Thursday). The change would decrease the quiz section size from 40 students down to 27 students, with three quiz sections associated with each lecture section.

3.3 More time in quiz sections

Quiz sections currently meet twice a week for 50 minutes. The change would have quiz sections still meet twice a week, with one of those meetings being 50 minutes and the other being 80 minutes. This longer quiz section meeting has a number of advantages.

A. More teaching opportunities

The department is working on developing classroom activities that are too involved for only 50 minutes. In-depth worksheets and group work on more complicated problems will give students more in-class experience developing the difficult problem-solving skills they will need in the future, as well as a more complete immersion in the techniques of calculus which they are learning.

B. More student-TA contact time

C. More flexibility

Midterm exams could be given in the longer quiz section meetings, reducing the time pressure on students in 50 minute exams and freeing up more lecture time.

3.4 Community college teacher involvement

Community college teachers will be involved in a sabbatical program at UW, teaching some classes at UW and interacting with the faculty and TAs of the Math Department at UW. This should improve channels between UW and community colleges in both directions. Those who visit UW will take back to their community colleges a better understanding of what is expected of students at UW in the courses they teach and subsequent courses, and the faculty and TAs at UW can learn from the visitors' teaching experiences, observations, and methods.

4 Means of assessment

There are two purposes in assessing how well these changes improve our success in reaching the objectives in our calculus courses. **Formative assessment** focuses on determining how well our overall objectives are being accomplished with the view toward making changes to make ongoing improvements. **Summative assessment** focuses on determining how well our overall objectives are being accomplished with the view toward deciding whether to continue with the current changes. There will likely be more formative assessment early in the three-year trial term (2001-2004), shifting to more summative assessment as the

three-year term proceeds. Many of the means of assessment will provide both formative and summative information, while some will be more focused on one or the other.

A key tenet of educational assessment is that every instrument is flawed, in fact, almost fatally flawed. There are too many different causes which could give the same effect. Relying on one instrument would give very skewed results. We have been encouraged to use many means of assessment, and to consider the overall message from all these means together.

These are the means of assessment we are planning to implement. We may develop others as we proceed, and we may find that some of these are not possible to implement effectively. In any event, we will implement a variety of methods of assessment, including as many of these listed below as possible, to provide a multi-faceted view of the success of the changes.

Because of the large number of sections that will be offered, some of these means of assessment will be applied to a representative sample of the sections of calculus offered, while others will be applied to all sections.

4.1 Surveys

A. Student surveys

(1) Students in calculus classes

a. Entering survey

A survey at the beginning of a course to assess incoming student expectations and experiences.

b. Student evaluations

OEA will help us write additional items to include with the standard end-of-the-quarter student evaluations to help assess progress toward our objectives.

(2) Former student surveys

A good source for student impressions of the value of the smaller lecture sections, smaller quiz sections, and longer quiz sections in Math 124/125 is our students in Math 126, which will be run for the time being on the format we have been using in 124/125/126 up to this time. At the end of 126, students will have experienced both formats, and can comment on the relative merits of the different formats.

B. TAs

We will survey TAs in the middle of the quarter and at the end of the quarter to

get their input on what is happening in the courses: what things they are trying to do, what is working, and what isn't. These surveys will become part of the "course portfolio" described below.

C. Instructors

We will survey instructors in the middle of the quarter and at the end of the quarter to get their input on what is happening in the courses: what things they are trying to do, what is working, and what isn't. These surveys will become part of the "course portfolio" described below.

In particular, the insights obtained from community college instructors visiting UW in the community college sabbatical program will bring valuable perspectives from outside UW.

4.2 Interviews and focus groups

We plan on interviewing representatives of several groups of people related to our calculus courses. As part of this process, CIDR has offered to help with student focus groups and small group instructional diagnosis (SGID).

- A. Current students**
- B. Former students**
- C. TAs**
- D. Instructors**
- E. Client department instructors**

4.3 Student performance

A. Common quiz problems

Ideally, it would be nice to give the same problem on a common final exam over a number of years to assess how well students are performing at the same task. Unfortunately, students use previous exams extensively in their studying for exams, so it is not possible to replicate similar levels of (un)familiarity with a problem over a period of several quarters or years, even if the problem is modified slightly. It would be possible, however, to give similar problems on a quiz, around the seventh week of a quarter, and monitor the results over a period of time.

B. Diagnostic tests

We plan on giving diagnostic tests at the beginning of Math 125 and Math 126 to compare the retention of material learned in Math 124 and Math 125 at the beginning of the following course.

C. Class performance in client departments

OEA has offered to track students from Math 124 and/or 125 in their courses and majors as they proceed through their undergraduate programs.

4.4 Observation of lectures/quiz sections by trained observers

CIDR will help in both observation and in training observers from the Math Department to document student questions, interaction, behavior, and satisfaction in lectures and quiz sections.

4.5 Course portfolios

Each quarter, a representative selection of sections will provide course portfolios. These will include at least the following items.

A. Representative exams

Copies of representative student papers (with names removed) for each exam (midterms and final) and some quizzes (including the “common quiz” problems mentioned above). For each exam, three student papers will be copied: one from the high range, one from the median range, and one from the low range.

B. Report by TAs on effectiveness of teaching strategies

C. Report by instructors on effectiveness of teaching strategies

4.6 Baseline data

Some data will be gathered this academic year (2001-2002) in Winter and Spring quarters to serve as baselines for comparison.

5 Process of evaluating success of changes

5.1 Time table

As a first approximation to the process of evaluation, we propose the following time table.

A. Semi-annual reports

The Math Department will provide to the Dean's Office semi-annual updates on the outcomes of the assessments made so far. They will be delivered in Winter (after Autumn quarter assessments are gathered) and in Summer (after the entire academic year assessments are gathered), starting in Winter 2002.

B. Semi-annual meetings

After these reports are delivered, representatives of the Math Department and the Dean's Office will meet to discuss the outcome of the assessment instruments to date. (The Math Department wants to provide ongoing communication with the Dean's Office regarding what is going on with the calculus courses. The initial reports are likely to be informal. If possible, members of CIDR and OEA staff could be involved in these meetings to help us interpret the results. Hopefully, this process of ongoing communication and reviewing the assessments will make it increasingly clear over the three-year term of the Tools for Transformation grant to both the Dean's Office and the Math Department whether or not the changes have been sufficiently successful to warrant long-term funding from the College.)

C. Final decision on permanent funding

Because offers for new TAs to staff classes in the 2004-2005 academic year would have to go out in Winter 2004, the decision for permanent funding (to start in the academic year 2004-2005, the year after the Tools for Transformation grant expires) would have to be made by February 15, 2004. This decision would be based on the report in summer 2003, the full assessment data gathered, and input from CIDR and OEA on the meaning of the gathered assessment data.

D. Possible alternative time table

It may be desirable to have assessment data from the full three-year term of the Tools for Transformation grant before making a final decision on permanent funding. One possible alternative would be for the Dean's Office to provide temporary funding for one year (the academic year 2004-2005), with a final decision on permanent funding by February 15, 2005.

5.2 Understanding of "permanent funding"

This program will be run on a trial basis for three years. Given a successful outcome to the trial experience, and informed by analysis of the effectiveness of each of the components of the program, Dean David Hodge has reserved \$150,000 of New enrollment funding for this purpose and has agreed to provide an appropriate level of on-going funding, including

additional funding if warranted, to continue the program at the conclusion of the Tools for Transformation support. The allocation of funds for the Tools project and the reserved new enrollment funding are independent of other resource issues that may involve the Department and the College.

6 Appendices

OEA and CIDR have provided proposals for the help they can provide with this assessment, and the costs involved; copies are attached.

- 6.1 A Draft Proposal for OEA's Role in the Math (Tools for Transformation) Evaluation**
- 6.2 Possible CIDR Involvement in Math Department Assessment of Changes in 124 & 125**