

Report on Standards in Freshman/Sophomore Calculus

February, 2001

I. The Committee's Charge

The Ad Hoc Committee on Standards in the Freshmen/Sophomore Calculus sequence was appointed by the Department Head and charged to respond to the perception that too many students are entering our courses, particularly 2214, 2224 and other upper division courses, without having acquired even the basic prerequisite skills in the preceding math courses. The committee was further charged to submit two proposals for rectifying these perceived problems, and that its recommendations have student success, not screening, as the primary goal and be amenable to implementation without a substantial commitment of new resources.¹

II. Summary of Concerns and Faculty Input

The committee solicited comments from all faculty and graduate students. Although not everyone is convinced that there is a problem, it seems that a large majority of faculty responding are. The problem in brief seems to be that a significant group of students (not necessarily a majority, but a consistent cohort) are moving through our main 1205 - 2224 sequence without acquiring competency in basic skills. Polynomial algebra, trigonometry, basic differentiation and integration techniques have been cited most frequently. Although there is some concern about the weakening background of entering freshmen, more of the concerns seem to focus on things students should have learned here. General issues that faculty brought up as they explained the problem follow.

Expectations

Many of the comments and observations focused on low or misguided expectations that are communicated to students. Some of the concerns are:

1. Low expectations result in students forgetting major topics or never adequately mastering these topics initially. Students focus their effort only on what they believe is expected of them.
2. Low expectations (among other things) may have caused some faculty to avoid these courses, further weakening their involvement in the planning and oversight of them.

¹ The Ad Hoc Committee released a draft report in April 2000 and solicited comments from the faculty, but did not have time to revise the report in Spring 2000. The Calculus Committee considered the report in detail in Fall 2000, but decided that it did not make sense for members of the Calculus Committee to redo the work of the Ad Hoc Committee in order to revise the draft report. Instead, revisions were made by members of the former Ad Hoc Committee who were also on the Calculus Committee, with some help from other members of the Calculus Committee.

Some ways that inappropriate expectations may be communicated include emphasis on:

- poorly designed multiple choice tests that cultivate “answer guessing” as opposed to the ability to work problems independently;
- group vs. individual responsibility for learning;
- group planning and organization as opposed to the actual mathematical content of the group project;
- simply clocking some required number of hours at the Emporium or elsewhere²;
- non-mathematical aspects of lab assignments;
- inadequate amount of graded written work; and
- syllabi that do not include adequate coverage of topics (e.g., “watered down”).

Other related comments include:

- Some faculty may be afraid to maintain high standards because they fear retribution for giving low grades. (Thus, there needs to be a way to deal with inadequately prepared students that avoids this fear.)
- A system of skills exams (e.g., the Oregon State idea or something like it) would create an expectation for the students that those skills are important.

Study Habits and Work Ethic

Although it may be largely beyond our control, a number of students seem unable to apply themselves to learning mathematics without some express instructions to follow. Whatever we might decide to do in the way of remediation needs to deliberately cultivate these skills. This is also related to the expectations issue; students need to understand that a certain work ethic regarding written homework is expected (and necessary to succeed).

Diversions of Instructional Effort

The large amount of time consumed by grading labs³ (for instance) has replaced time that might otherwise be (or formerly was) spent reading students’ more traditional homework. The very small amount of written work that is actually graded in some sections is another way that we implicitly set expectations for the students that undermine their learning. 1205 has been mentioned in particular as a course in which faculty time has been redirected for noninstructional activities. (Emporium floor hours, for example, are not solely directed at 1205 students.) Several recent 1205 instructors felt that the schedule/syllabus does not allow adequate classroom time to teach essential skills, and consequently students are not learning them adequately.

Inadequate Assessment

- Some faculty raised concerns that multiple choice exams are not an adequate method of assessment. They do not think answer-only exams should extend much further into our courses.

² This is not being done in any of the Engineering Calculus courses in the 2000-2001 academic year.

³ This is not a problem in any of the Engineering Calculus courses in the 2000-2001 academic year.

- Basic Skills Tests (BST) in 1206: Although motivated by the same concerns as our committee, the current BST tests are not contributing enough in addressing the issue.
- Common Time (CT) exams: The feedback mechanism that might allow the common time exams to improve the efficiency of our courses needs to be improved. For instance, among those preparing common time exam summary reports, there seem to be different understandings of what "goals well met" means.⁴
- A concern was raised that assessment has been focused on generating favorable publicity.
- Regarding a different type of assessment, we don't know how to identify those faculty who are teaching with high standards or in an especially effective way, so that they can be rewarded and/or emulated. In fact, concern was raised that some teachers are not measuring up to instructional standards in fundamental courses—not being prepared to lecture, not being able to do examples or homework without mistakes and much loss of time.

Inadequate Course Planning and Oversight

- Professorial-rank faculty are involved in the CT exam reports, but relatively few are involved in actually teaching 1000-level courses and so are not in a position to help design improvements. They should be more involved in teaching, syllabus revisions, and other course design planning. There also needs to be some oversight of the various initiatives and ideas that are being developed for individual courses. The day-to-day aspects of individual courses can be managed independently, but there seems to be no one at the helm for the combined effectiveness of these courses. This is ultimately the role of the Undergraduate Program Committee. But even beyond that, a larger and more diverse group of faculty needs to be engaged with the design of these courses.
- There should be a mechanism for feedback from subsequent courses to be reported to those responsible for syllabus and/or course design revisions, not to mention the individual instructors.

Remediation Resources

- Some people feel that we do not have enough remediation resources for students who are deficient in basic skills from high school or previous courses.
- Another concern, however, is that many students do not fully take advantage of resources we do offer, such as ESP, the tutoring lab, and individual instructor help.

III. Further Background

There was not sufficient time for a detailed examination of each course in the freshmen/sophomore calculus sequence so, given the importance of Math 1205 in the sequence and given our perception that there is widespread faculty discontent with that course, the committee focused much of its attention there. We closely examined student performance on the common time final exam for Fall 1999. The average score on the

⁴ This has now been standardized.

exam was 7.9 of 16 or 49%. There can be much debate about the particulars of the exam. Indeed, comments from some of the teachers indicate that, in their view, the exam required considerable algebraic and arithmetic calculations and was somewhat long. Such objections are not sufficient, in our opinion, to entirely explain the poor overall performance. For instance, the exam certainly included straightforward questions that measured very basic skills, yet the maximum overall performance on any single question was 79%. As examples, 22% of the students were unable to calculate the limit of a rational function with a removable discontinuity, 35% could not find $f'(x)$ for $f(x) = x\sqrt{2x^3 - x + 1}$, and 41% of the students were unable to compute a derivative that required a simple application of the quotient rule.⁵

Approximately 9% of the students enrolled in Math 1205 in Fall 1999 failed the course. We would conclude, therefore, that some number of students are successfully continuing to Math 1206 without having demonstrated, at least on the final exam, that they have acquired even the basic skills required to succeed in 1206. This conclusion is further justified by the performance on the first “gateway test” given in Math 1206 during Spring 2000. That test covers basic differentiation and students are given multiple opportunities to complete it, yet 19% of the students did not pass the test. Indeed, it is troubling that some of those students who did pass required numerous opportunities to do so, indicating a less than desirable grasp of the basics of differential calculus.

IV. Proposals

Two proposals are offered in fulfillment of the charge to the committee. The specifics of these proposals are not detailed enough for implementation yet. For those which the faculty endorse in principle, it is part of the proposals that the additional details needed and specifics needed for implementation be developed.

The proposals are intended to:

- motivate and assist student learning so the student leaves Math 1205 or 1206 with the basic skills necessary for success in subsequent courses, and
- to help students begin 1206, 2214, or 2224 by recovering those crucial prerequisite concepts they will need to survive the course.

Proposal 1: Basic Skills Testing

A **Basic Skills Test**, given in the latter part of the semester, tests the fundamental skills that were presumably acquired in the current course and that are necessary to continue successfully in subsequent courses. There should be broad consensus among the faculty

⁵ The performance on the common time final exam for Fall 2000 was substantially different. The average score was 9.52 out of 15 (or 63.4%). 85% of the students could calculate the limit of a rational function with a removable discontinuity, 87% could find the derivative $f'(x)$ for $f(x)=5x/(x^2+3)$, and 90% could find the derivative $f'(x)$ for $f(x)=x \sin(4x)$.

that the questions appearing on Basic Skills Tests are basic to the point that all students who pass the course can reasonably be expected to answer all of them correctly. Basic Skills Tests are written tests, with individual versions of the test generated from a large database of questions. These tests would be designed for rapid hand grading, with no partial credit given.

A **Practice Test** is some easily accessible version of a Basic Skills Test. The purpose of the Practice Test is to assist a student in preparing for the Basic Skills Test. A student who takes, but does not pass, a Practice Test will be provided with a diagnostic report indicating weaknesses and, where remediation is appropriate, suggesting the appropriate Learning Modules. (For purposes of this discussion, a **Learning Module** is a brief online presentation of a specific topic. A single module might take a variety of forms, including taped lectures, commercially available materials, public software, and/or interactive materials created in-house.)

Students may take the Practice Test as many times and as frequently as they wish.

With these definitions in mind, we propose specifically that:

- **Each Math 1205 and 1206 student be required to take a Basic Skills Test. Their performance is to be evaluated on a pass/fail basis, with a high performance level (e.g. 90% or better) required for passing.**
- **Each concept tested in a Basic Skills Test also be tested in the Practice Tests and have an associated Learning Module.**
- **A Basic Skills Test count as 10% of the student's grade and the student receives the entire 10% or nothing.**
- **A student be permitted a maximum of three attempts to pass the Basic Skills Test with a required lapse of at least a week between attempts.**

Proposal 2: Prerequisite Testing

A **Prerequisite Test** is a multiple-choice, online test, given early in the semester. It covers exactly those topics that are prerequisite for the current course and are not specifically revisited in the current course. The test should be designed (i.e., the number of questions, the breadth of topics, the choice of distractors) so that a pass reasonably validates a student's grasp of the prerequisite material. It is not an attempt to measure how much of the material in a previous course is remembered, but is focused only on making sure that each student has the basic knowledge required to pass the current course. The amount of knowledge necessary for a student to be competitive for an A in the current course will greatly exceed what is represented by the test. Failure to eventually pass a Prerequisite Test should be such a clear demonstration that the student has not successfully acquired the prerequisite material that removal from the course would be justified. (See below regarding the actual consequences of failure.)

The database of questions for a Prerequisite Test should be huge. Questions for the test should be created with the assistance of individuals with some expertise in designing multiple-choice exams.

We propose in particular that:

- **Each Math 1206, 2214, and 2224 student be expected to pass (with a score of 90% or above) a Prerequisite Test. All students in the course will be strongly urged to attempt the test during the first week of the semester, and be informed that passing the test is an expectation for their completion of the course. All prerequisite testing should be completed one week before the last drop date.**
- **Each concept tested in a Prerequisite Test have an associated Learning Module delivered from the Emporium servers. (A Learning Module is a brief online presentation of a specific topic. A single module might take a variety of forms, including taped lectures, commercially available materials, public software, and/or interactive materials created in-house.)**
- **The possible consequences of failure to eventually pass the prerequisite test be considered and explored, and an appropriate selection adopted. Some particular possibilities to consider include (but are not limited to) 1. removal of the student from the course, 2. permission to retake the prerequisite course for credit if they agree to voluntarily drop the course, 3. mandatory remedial work and/or supplemental activities, 4. a hold on graded work after the first hour test, 5. a failing grade (or grade reduction) in the course for which the student is currently enrolled.**
- **Students who fail a Prerequisite Test be provided a diagnostic report indicating the skills where remediation is required and not be permitted to take another version of the test until there has been documented remediation. Apart from this constraint, students may take the test as many times as they like before the deadline.**

Clearly there are a number of practical issues to be resolved in order to implement this proposal. We hope, however, that the intent is clear: to communicate to the student that as a requirement of the course they are responsible for a minimum level of proficiency with the prerequisite material, and if they cannot demonstrate that minimum proficiency then we expect them to take some set of appropriate remedial measures. If those remedial measures fail to restore them to a minimum level of proficiency, then we consider their continued enrollment in the course inappropriate.

V. Supplemental Recommendations

In addition to the two specific proposals offered above, the Standards Committee also suggests the following additional measures for serious consideration by the Department.

Recommendation 1: We recommend exploring the possible mechanisms for effectively increasing the current prerequisites for Math 1206, 2214, and 2224 so as to require a grade of C or better in each prerequisite course.

It is recognized that it may not be possible to institute this change in prerequisites in a way that applies to all students. The suggestion is that various mechanisms to achieve this same effect be considered. For instance some other Departments might be willing to work with us in imposing such prerequisites for their majors in particular. We also recognize that the department does not have sufficient office staff to enforce these prerequisites so, standing alone, this recommendation would have minimal impact. In the context of basic skills testing and prerequisite testing this recommendation becomes another means of communicating to the student the gravity of proceeding to a subsequent course without the basic prerequisite skills.

We assume that most students granted admission to Virginia Tech are capable of obtaining a bachelor's degree. Unfortunately, many students entering Tech in the sciences, mathematical sciences, or engineering will not be successful if they persist in their initial choice of major. It is in the best interest of the university, the department, and these students that they be channeled as quickly and efficiently as possible into a more suitable program. In many cases, a grade of C- or D in a basic course is apparently not sufficient encouragement for the student to consider other options. A prerequisite of a C or better in subsequent courses reinforces the message and, perhaps, will motivate some students to change directions before they reach the point of failure.

The department is currently engaged in numerous assessment activities: common time final exams and their summarizing reports, basic skills tests (1206), senior interviews, statistical analysis of grade distributions, various student surveys, and external reports such as the Emporium assessments by Betsy Little and John Muffo. If implemented, the recommendations of this report will add significantly to those activities.

Most of the current efforts constitute "summative" assessment, i.e., reporting on current activities for the benefit of those outside the department. We have little "formative" assessment, i.e., critical examination of our successes and failures for the purpose of identifying where changes or modifications are needed. In other words, our present assessment activities are providing very little constructive feedback for our instructional efforts.

The highest quality assessment accomplishes nothing if the ideas generated are not put into practice. There must be someone responsible for the continuing improvement of each course. This person should play an important role in determining what issues must be addressed by the formative assessment and be in a position to actualize the conclusions drawn from that assessment. This is the person that teachers of a particular course would direct their observations and suggestions to and this is the person who would act as advocate for the learning needs of the students enrolled in the class. To accomplish these tasks, the person in this role must be a strong teacher and a tenured (preferably a Full) Professor.

Recommendation 2: We recommend that a tenured (preferably Full) Professor be assigned as the leader to each of the large Freshman-Sophomore courses. The Course Leader would be responsible for overseeing appropriate modifications of the course in concert with the Department Head and the Undergraduate Program Committee.⁶ He or she is expected to be in close touch with the Course Coordinator, those teaching the course, and those assessing the course. It is expected that this person would be dedicated to providing the best possible learning experience for the students with available resources and would represent the resource needs of the course to the Department administration.

Recommendation 3: We recommend that the Assessment Committee be expressly charged to review our numerous assessment activities with the purposes of:

- Putting into place feedback mechanisms for our current efforts, including those implemented as a consequence of this report.
- Developing, together with the course leaders, new critical/formative assessment efforts where we need more information about our current practice.
- Supporting the learning enhancement efforts of the course leaders.

Until recently there was no effort to carefully review the results of our various Common Time Exams. Now that we have begun to do so, with the preparation of CTE reports, we see that there are indeed things we can learn about the effectiveness of our courses.⁷ To wit, several of the Fall 1999 common time exam review reports cite the need for improved data in reviewing common time exam performance. The 1114 report cites a significant group of students (17%) who apparently learned very little from the course. Other common time exam reports point out problems in preparation of the exam questions, the effectiveness of prerequisite courses and even topics that are missing from some prerequisite course syllabi. There also seems to be a difference in understanding of what “goal well met” means among the different report authors.⁸ The Assessment Committee should be encouraged to continue to provide this essential “feedback” link.

The 1206 Basic Skills Tests are one place where additional planning is needed to move beyond purely summative activity to a formative role. The tests were initiated by concerns similar to those of our committee. Yet there seems to be no concerted effort to use the results of the tests to adjust syllabi or otherwise respond to problem areas that the tests might find. If the Basic Skills Tests are not subsumed by other recommendations of this report, the Assessment Committee should design a formative component for them.

The senior exit interviews are another example of summative assessment (in this case developed for purposes of external reporting) which we could use more profitably to strengthen the effectiveness of our undergraduate program.

Overall, the Assessment Committee needs to act as a sort of ombudsman to insure that all the lessons and constructive criticisms that our disparate assessment activities produce

⁶ For the 2000-2001 academic year, 1205 and 1206 each have a pair of co-coordinators. For each course, one of the pair is a Full Professor and one is an Instructor.

⁷ Data from common time exams was used in planning revisions of 1205 and 1224.

⁸ This has now been standardized.

are brought to the attention of those who are in a position to act on them, from individual instructors, to course coordinators, up to the UPC and the Department Head. Where there is a need for information not currently available (e.g., particular types of data for common time final results), it should be the Assessment Committee's task to develop that information. We believe that the Assessment Committee understands that its task includes such formative as well as summative functions. But the department's formative assessment is much less developed than the summative, so that an increased emphasis is needed on developing information for the purpose of critically evaluating and improving all our instructional efforts.

Recommendation 4: We recommend a coordinated review/revision of the 1205 - 2224 sequence.

- Identify and eliminate those activities and components which are creating improper expectations and/or diversions of instructional effort.
- Determine whether the level of expectations reflected by the syllabi (both content and homework) are appropriate. In particular, the designs of the courses/syllabi must make the topics and skills we want students to concentrate on (ability to think and reason independently, ability to recognize concepts in new contexts, certain specific calculational skills, ability to complete written work, and so forth) the focus of what the students actually need to do to pass. We must make the essentials essential.
- Although we can not expect real conceptual facility by all students, there needs to be adequate exposure to it for those students who will need it later.
- We must review the type of Computer Labs currently being used to see if they utilize technology in the most appropriate and most effective way for accomplishing the learning goals of the course. As a possible alternative, for example, we could assign additional homework problems which must be done using computer software. Then, perhaps, we could focus testing of this type of homework problem at the Math Emporium and free the classroom teachers to help students with the core material.
- We should find ways to provide more reading of students' written work.
- We should reinforce material already covered by building into the syllabus of courses in the engineering sequence ongoing review problems.
- 1205, in particular, needs an earnest review. The possibility of restoring 1205 to a 3-hour lecture format should not be ruled out without an adequate discussion of the resource tradeoffs that would be involved.
- There needs to be an effective method of communicating changed expectations to those who are teaching these courses. Along with this there need to be methods to protect teachers whose in-class evaluations decline as a result of seriously addressing these changed expectations.