# CALCULUS READINESS ASSESSMENT AND REMEDIATION USING MAPLE T.A.
## *A MODEL FOR CREATING AND IMPLEMENTING COMPUTER-BASED ASSESSMENT AND REMEDIATION*

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***Abstract***

*Frustration over poor student retention of prerequisite course materials served as the catalyst for creating online "readiness" exams and tutorials in the three-course calculus sequence. In this paper, the authors provide a model for creating and implementing computer-based assessment and remediation using Maple T.A.*

**Introduction**

The problem that Eastern Connecticut State University's mathematics faculty faced in its three-course calculus sequence is mirrored across the country. As students move through the sequence they forget skills and concepts learned in earlier courses, they often have an unrealistic expectation that their present instructor should review all previously learned material relevant to the present course, and they try to hide their lack of knowledge, which can lead to disaster at the end of the semester. Frustrated by this situation, mathematics faculty at Eastern decided to take action in the form of instituting calculus readiness exams and remediation at the start of each course in the calculus sequence.

**Strategic Plan**

In order to translate the idea – calculus readiness exams and remediation – into reality a strategic plan was needed. Our strategic plan included the following:

- Identify appropriate mathematics assessment software
- Obtain funding
- Outline exam content areas
- Develop a procedural plan and implement the plan
- Analyze results and revise assessments and/or courses
- Disseminate results

Identification of Software

The first step, identification of the mathematics software, was the easiest step; we selected *Maple T.A.* Our selection was influenced in part by the fact that we had been using the computer algebra system *Maple* in Calculus courses since 1991. So, there was familiarity with the *Maple T.A.* software (*Maple 10*'s kernel is embedded in *Maple T.A.*)

and its creator, Maplesoft. A salient feature of this assessment software is that *Maple T.A.* can identify and correctly grade equivalent forms of student answers. In addition, *Maple T.A.*'s randomly-selected-constants design feature is useful in creating different questions with the same mathematical structure. Parenthetically, given that the Mathematical Association of America (MAA) and Maplesoft are presently collaborating on online assessment/placement exams is further endorsement that we made a wise choice in selecting *Maple T.A.*

Funding

The next hurdle was funding. We were rather creative in this area and were able to get funding for Maple T.A. worked into a Fund for the Improvement in Post Secondary Education (FIPSE) grant that targeted creative initiatives in the use of computer-technology to support developmental mathematics. In addition, the authors were able to obtain several small grants to support our work from the Connecticut State University System's Learning and Assessment Grant Program. Most recently, the authors were able to convince the Connecticut State University (CSU) System Office to pick up the cost of a site license for Maple T.A. for the four institutions in the CSU System (Western, Central, Southern and Eastern). All we can say about funding is: "Where there is a will there is a way!"

Identification of Calculus Topics

The next challenge was deciding on the calculus content for the entry exams. As a department, we had in the past generally agreed on the textbook and chapters we would cover each semester. However, we had never come to an agreement on which topics were essential for student success in the next course in the calculus sequence. A Calculus Committee was formed and charged with the task of identifying a minimal list of core topics for *Calculus I, II* and *III*. Once completed the Core Topics for *Calculus I, II,* and *III* were presented, refined and accepted by the entire mathematics faculty. These lists served as the basis for Eastern's Calculus Assessment System – Calculus I, II and III entry exams and tutorials.

Procedural Plan

Crucial to the Department's plan for assessment of its Calculus sequencewas the concept "start small and build in small increments." Hence, the plan called for beginning with a single course, *Calculus II* and included the initial three stages listed below:

*Stage I*

- Learn the software and create an entry exam for *Calculus II*
- Pilot test entry exam on students entering *Calculus II*
- Analyze results
- Refine exam
- If needed, adjust core topics for *Calculus I*

*Stage II*

- Create tutorial for *Calculus II*
- Create entry exam and tutorial for *Calculus III*
- Implement entry exams and tutorials in *Calculus II* and *Calculus III*
- Analyze results
- Refine exams and tutorials
- Adjust core topics and/or instructional approaches for *Calculus I* and *II*

*Stage III*

- Draft Core Topics for Entry into *Calculus I*
- Create entry exam and tutorial for *Calculus I* based on Core Topics
- Implement entry exams and tutorials in *Calculus I, II,* and *III*
- Analyze results
- Refine exams and tutorials
- Adjust core topics and/or instructional approaches for *Calculus I, II,* and *III* (and possibly in courses below *Calculus I* or above *Calculus III*)

Over time, additional courses (developmental mathematics courses are next) are planned for Eastern's *Maple T.A.* Assessment System. Based on analysis of the assessment results, the mathematics faculty will revise course content and/or instructional approaches.

It is interesting to note that members of the Psychology Department have inquired regarding the possibility of using *Maple T.A.* to create entry exams for their Research Methods course. Hence, we are now looking for opportunities to expand the use of Maple T.A. to other disciplines.

Implementation

The first implementation of both entry exams and tutorials was fall 2004. Entry exams to incoming *Calculus II* and *Calculus III* students (approximately 60 students) were administered at the beginning of the semester. For those students who did not earn a passing grade of 75, mandatory tutorials were provided. The questions on the entry exams and tutorials focused on the list of Core Topics for *Calculus I,* and *II* (arrived at by consensus of the mathematics faculty). The Core Topics lists were made available to students prior to the entry exams. Students entering *Calculus II* were tested on material drawn from the Core Topics for *Calculus I* (differentiation); the students entering *Calculus III* were tested on material drawn from both the Core Topics for *Calculus I* and *II* (differentiation and integration). As of this date, revised assessment exams and tutorials are administered at the beginning of every semester, with assessment of students entering *Calculus I* for the first time in spring 2007. To date, 367 calculus students have been assessed by our *Maple T.A.*-based Calculus Assessment System.

Creating the *Maple T.A.* question banks needed for the Calculus Assessment System was a time-consuming task. The authors split the work of creating the entry exams and

tutorials. Dr. Keating created the entry exams, which tested both content theory and the use of technology (students' ability to use the TI-89 graphics calculator to solve problems in calculus). Dr. Davis created the tutorials which were set up as mastery sessions in *Maple T.A.* Use of mastery sessions allowed the creator to force students to work through problems (or groups of problems) in a particular order and block students' progress through the tutorial until they answered questions correctly.

Perhaps the biggest obstacle has been to get students to complete the entry exams and tutorials within the first few weeks of the course. When the entry exams and tutorials were first implemented, calculus instructors were forced to give students grades of Incomplete for failure to complete the entry exam or tutorial prior to the end of the semester. That meant faculty had to track down students and then Dr. Keating or Dr. Davis had to reopen the entry exams/tutorials for those few individuals who failed to complete the assessments. Subsequently, the Department has instituted a policy that requires students to complete the entry exams within the first two weeks of class and the tutorials within the first three weeks of class. Failure to meet these deadlines results in a drop of one letter grade for the final grade. This policy will take effect for the first time fall 2007.

**Assessment Results and Changes**

*Maple T.A.* provides an abundance of statistical information at both the course level and individual student level. For example, on the entry exams, in addition to a list of students' final scores, faculty can access the dates on which students took the exam and the amount of time they spent on the exam. The percentage of students who answered each question correctly as well as looking at an individual student's answers can be determined. This type of information is extremely useful in identifying weaknesses in the calculus sequence as well as an individual student's content weaknesses.

In terms of weaknesses at the course level, it was discovered that:

- *Calculus I* students have some difficulty in finding the equation of a line. (This result was a surprise.)
- *Calculus II* students have difficulty in applying the chain rule for differentiation. (No wonder students have trouble with the substitution technique in integration!)
- *Calculus III* students have difficulty with summation notation.

Mathematics faculty responded to these discoveries by strengthening how these areas are addressed in previous courses. In the case of summation notation, for example, this topic has been added to *Precalculus* so that students have an opportunity to work with summation notation both in *Precalculus* and in *Calculus II*. In addition to specific mathematics content weaknesses, the Department learned that students have serious weaknesses in the use of technology, specifically the TI-89 graphing calculator, to solve calculus-related problems. Calculus instructors are working to better integrate use of the TI-89 calculator into their courses.

Although there has been progress in adjusting course curricula in the areas of identified weaknesses, it should be stressed that the Department is at an initial stage of prerequisite

course assessment and will continue to refine course content and instructional approaches as directed by the data analysis.

**Dissemination of Results/Continued Research**

Dr. Keating and Dr. Davis have presented their strategy and demonstrated their application of *Maple T.A.* for online assessment at a number of conferences and at several universities. Because of their novel approach in the use of technology to assess student retention of prerequisite course material and their provision for remediation, Dr. Keating and Dr. Davis will be featured by author Peggy Maki in her revised textbook on assessment. Furthermore, Dr. Keating and Dr. Davis' methodology will be highlighted as a case study by Maplesoft. Both authors plan to continue their work in assessment. In particular, Dr. Keating has been awarded a spring 2008 sabbatical to continue her research in assessment and its application to the use of online technology. Hence, additional presentations and research articles are expected in the future.

***Information on Maple T.A.***

Question Bank

For the calculus entry exams and tutorials, the *Maple T.A.* Question Bank Editor was used to create question banks for each exam and tutorial. After creating and naming a question bank, it must be saved and uploaded to the *Maple T.A. System*. More often than not, *Maple-Graded* questions which were generated algorithmically were chosen; however, multiple-choice, fill-in-the-blank, clickable image, and graphical questions are also possible.

Assignment or Mastery Session

Assignments (in a variety of formats – exams, mastery sessions, study sessions, etc.) are created by selecting questions from a question bank. Once the questions are selected, policies must be set. Policies can include restricting the number of attempts a student is allowed to complete the assignment, setting the beginning and ending dates, and specifying whether students can view hints during the assignment or solutions at the end of the assignment.

Grade Book

The *Maple T.A. Gradebook* records student statistics consisting of student names, identification numbers, dates when the assignment are accessed, the time on task used for the assignment or mastery session, grade earned and so forth. The instructor can access assignment statistics such as the mean and standard deviations of the scores, as well as the lower quartile, median and upper quartile of the scores. At the question level, instructors can view the success rate, the $p$-value and the $d$-value and they can view individual student assignments.