A MODEL FOR COMPUTER-BASED ASSESSMENT AND REMEDIATION: INTERMEDIATE ALGEBRA THROUGH CALCULUS

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Abstract

In this paper we discuss our approach in addressing two very important and pressing issues that many Mathematics Departments are facing these days, namely assessment and remediation. In recent years Eastern has developed a computer-based assessment and remediation system consisting of tests, assignments, practice quizzes and tutorials with the dual goal of achieving both efficiency and objectivity. The software chosen for this system is Maple T.A.

Introduction

The Mathematics Faculty at Eastern Connecticut State University faces two important problems, assessment and remediation. As is the case for many institutions, particularly public universities, departments are expected to develop and implement procedures for objective assessment of student learning outcomes. However, even before developing an assessment instrument, mathematics faculty were all too familiar with the universal problem that many students taking a sequence of courses (such as *Intermediate Algebra* to *Precalculus* to *Calculus I*, *II*, and *III*) fail to retain sufficient knowledge from one course to another to successfully complete the next course in the sequence. This situation causes a significant amount of frustration both for faculty and for students. Typically this problem is addressed by adding a review at the beginning of the semester. However, review time must be limited or else the curriculum will not get covered. Therefore, it is important to identify the weakest points in students' skills/knowledge and address those areas during review while at the same time getting students to take a more active role in their own review process. In order to address these problems, Mathematics Faculty at Eastern decided to institute an assessment/remediation system for courses in the sequence *Intermediate Algebra* to *Precalculus* to *Calculus I*, *II*, and *III*. The system consists of entry exams to assess students' readiness to take the course and, upon identification of insufficiencies, to introduce a remedial component. It became obvious that in order to do this efficiently, we had to enlist the help of technology.

Strategic Plan

It was clear from the beginning that it would take a long sustained effort to achieve our ambitious goals, and thus we began with careful planning. Our strategic plan contained the following basic components:

- Identify suitable assessment software
- Obtain funding
- Outline assessment content areas
- Develop and implement procedural plans
- Analyze the results and revise exams/remediation assignments
- Disseminate results – share with and learn from discussions with others

Identification of Software

The Mathematics Faculty had been using Maplesoft's computer algebra system *Maple* in calculus courses since 1991. Hence, it was quite natural to consider adopting *Maple T.A.*, mathematics assessment software from Maplesoft. The syntax and structure used in *Maple T.A.* is the same as *Maple's.* Unlike assessment software connected to specific textbooks, *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 and also assignment questions can be scrambled so they appear in a different order. Hence, exams can be created so that students sitting side-by-side will see different exams, which are essentially the same mathematically. *Maple T.A.* also supports the development of different types of assignments. For example, we found that mastery sessions (students must get one type of question correct before they can move to a new type) were ideal for creating tutorials. Another nice feature for tutorials is the capability of including one or more hints as a question component.

Funding

We were rather creative in this area and were able to get initial funding for *Maple T.A.* through 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, we obtained small grants to develop our assessment and remediation system from the Connecticut State University (CSU) System's Learning and Assessment Grant Program.

Identification of Core Topics for Assessment

Before designing assessment questions, we needed to decide on the core topics/skills that students should know upon entering each course in the *Intermediate Algebra* through *Calculus III* sequence. As a Department, we had in the past generally agreed on the textbook and chapters we would cover for each course. However, we had never discussed or come to consensus regarding which topics were essential for student success in the next course in the sequence. Implementation of a standard assessment across sections required a higher level of coordination of the content covered in each of the courses. We began development of our assessment system with the calculus sequence. An ad hoc Calculus Committee was formed and charged with the task of identifying three minimal

lists of absolutely essential Core Topics needed for student success in *Calculus I, II* and *III*. Once completed, the lists were presented, refined and finally 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, for students who failed the entry exams, tutorials. Subsequently, this process was expanded to include *Precalculus* and *Intermediate Algebra*.

Procedural Plan

It was clear that it would take considerable time to complete the creation of an assessment/remediation system that covered *Intermediate Algebra* through *Calculus III*. (At Eastern faculty have a four-course per semester teaching load as well as expectations for scholarly activity and committee work.) For that reason, the Department adopted the guiding principle "start small and build in small increments."

We followed our procedural plan for the calculus sequence:

- First, we developed the entry exam for *Calculus II*, which contained questions related to the Core Topics from *Calculus I*, the topics the Department had determined as essential for student success in *Calculus II*.
- Based on an analysis of data from the initial *Calculus II* entry exam, we revised the exam and developed the entry exam for *Calculus III*. In addition, we developed tutorials for *Calculus II* and *III*, which would be required assignments for students who failed the entry exams.
- To complete the Calculus Assessment and Remediation System, we developed the entry exam and tutorial for *Calculus I*. We also revised the entry exams and tutorials for *Calculus II* and *III*.

After each stage in the plan above, data generated by *Maple T.A.* was analyzed and used to revise entry exam and/or tutorial questions. In some cases, the Core Topics and course curriculum were adjusted in response to new understanding about areas of student weaknesses. Figure 1 shows a schematic of the procedural plan for the assessment and remediation system for the calculus sequence.

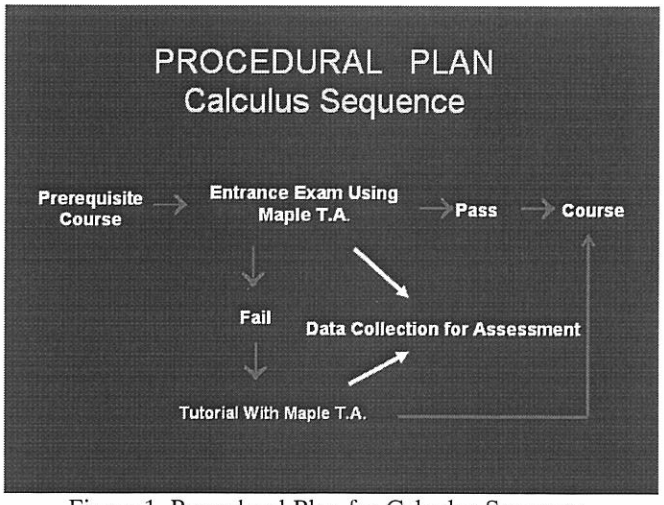

Figure 1. Procedural Plan for Calculus Sequence.

The plan for the assessment and remediation system for *Precalculus* and *Intermediate Algebra* differed somewhat from the system designed for the calculus sequence. Here the entry exams would be designed to give instructors base-line information on students' algebra skills. In place of a tutorial, a question bank was developed. Using questions from the question bank, instructors created their own assignments, modules, and practice quizzes, which were administered at various times during the semester.

Implementation

For each course the turnaround time for the cycle – create the assessment/remediation system (an entry exam and remediation component), pilot test the system in one section, analyze data, revise the system, and fully implement the system across all sections – was roughly an academic year. As we gained experience, the process sped up. Also, on nearing the end of the cycle for one course, we started working on the next course. By taking the slow approach of pilot testing each course's assessment and remediation system prior to full implementation, we saved ourselves a great deal of grief. Any software glitches or problematic questions in the entry exam or remediation component were isolated to one section and hence, any fallout was easily controlled by the instructor.

The first full implementation of the *Calculus II* and *III* Assessment/Remediation System took place in fall 2004. Entry exams to incoming *Calculus II* and *Calculus III* students (approximately 60 students) were administered at the beginning of the semester. 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). The Core Topics lists were made available to students prior to the entry exams and they were encouraged to review these topics before taking the entry exams. Students who did not earn a passing grade of 75 were required to complete a tutorial. The full implementation of the Calculus I Assessment/Remediation System took place spring 2007. Partial implementation of the *Precalculus* and *Intermediate Algebra* Assessment Systems took place in fall 2007.

Dividing the Work/Encountering Obstacles

Creating the *Maple T.A.* question banks for the course assessment/remediation systems was (and continues to be) a time-consuming task. The authors split the work of creating the entry exams and tutorials. Dr. Keating created the calculus 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 calculus 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. Dr. Davis and Dr. Yankov created the *Precalculus* entry exam; the development of an extensive question bank (from which review modules, assignments and practice quizzes are created) is ongoing. After pilot testing the *Intermediate Algebra* entry exam, we determined that the exam was too difficult. Although the entry exam sent

a strong signal to students that their algebraic preparation for *Intermediate Algebra* was inadequate (which was not a bad thing – students buckled down and got very serious very quickly), student performance on the entry exam was so poor that analysis of exam results provided little useful information.

The assessment software is developing rapidly. We have a dedicated server for the whole system, as recommended by Maplesoft. In the past, we encountered a few glitches in the software and a rather steep learning curve. We installed *Maple T.A.* 3.0 prior to the start of the fall 2007 semester. Although there are many new features in *Maple T.A.* 3.0 that we loved (some that greatly reduce the learning curve), we encountered a multitude of software problems during the 2007/2008 academic year. While technical support at Maplesoft was very cooperative and generally quick to respond, each of us (and our University Assistant) devoted considerable time to sorting out the problems that cropped up during 2007/2008. We fully expect that Maplesoft (and Maplesoft technical support in conjunction with our IT Department) will resolve the software issues prior to fall 2008.

Perhaps the biggest obstacle has been getting students to take the entry exams within the first two weeks of class and getting those students who fail the entry exams to complete the tutorials within the first three weeks, as required. We have been working on determining the right proportion of reward and penalty so that all students comply without faculty having to track them down. Currently, failure to meet these deadlines results in a drop of one letter grade for the course grade. Fall semester 2008, we hope to be able to administer the entry exams during class time – the obstacle has been finding an available computer classroom. However, students who fail the entry exam will still need to take the responsibility of completing the tutorials on their own time.

Assessment Results and Changes

Maple T.A. provides an abundance of statistical information at both the course level and individual student level. In terms of weaknesses at the course level, we have discovered:

- *Precalculus* students had significant problems with adding and dividing rational expressions
- *Precalculus* students struggled with the Quadratic Formula
- After a review of basic algebra at the beginning of Precalculus, students' algebraic skills improved (entry exam mean: 38.3; post exam mean 47.0). Although the exam scores of the algebraically weaker students improved, these students remained the weaker students. The algebraic gap between the weaker and stronger students remained about the same before and after the review.
- Students' problems with rational expressions persisted through *Calculus III*.
- A surprising number of *Calculus I* students were not able to find the equation of a line given two points on the line.
- *Calculus II* students had considerable difficulty with the Chain Rule.

Mathematics Faculty will respond to these and other findings by strengthening how these areas get addressed in previous courses or by strengthening coverage in a current course. In addition, given students' weaknesses in algebra, we plan to add more algebra content to the entry exams and tutorials in the Calculus Assessment/Remediation System.