CALCULUS READINESS ASSESSMENT AND REMEDIATION USING *MAPLE T.A.*

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Abstract

Frustrated by students' poor retention of prerequisite knowledge as they move through the calculus sequence? This paper provides a chronological report of our efforts to correct this situation by creating "Core Topics for *Calculus I, II* and *III*", obtaining funding, and harnessing the power of *Maple T.A.* to create, evaluate and grade online Calculus Entry Exams and Tutorials. Plans for the future are also noted.

Introduction

Eastern Connecticut State University (ECSU) is one of four campus sites that make up the Connecticut State University (CSU). Designated as "The Liberal Arts University", ECSU has a current enrollment of approximately 5,000 students, many of whom are first generation and/or nontraditional college students. The student body is quite diverse and about three-quarters of them are employed on a part-time basis in addition to taking classes. In 2004-2005, seventy percent of the full-time undergraduates received financial aid.

The calculus sequence is the cornerstone of the mathematics major; it is also required knowledge for other majors such as Computer Science and Biology. It is imperative that students retain skills introduced in the calculus sequence as well as strong algebraic skills for use in subsequent courses. Not only does failure to retain material learned in earlier courses affect students' performance in more advance courses within the mathematics major but also it adversely affects students' scores when they take the Graduate Record Exam (GRE), for example, or the Praxis II exam that is required for teacher certification.

There are many reasons why students might fail to retain prerequisite knowledge from the calculus sequence – time gaps between consecutive courses in the sequence, inconsistencies from one instructor to another, an increase in the complexity of the mathematics as students move through the sequence of *Calculus I, Calculus II* and *Calculus III*. However, one major reason is that students view individual courses within the calculus sequence as compartmentalized entities and do not step up to their responsibility to review before entering the next course in the sequence.

The Catalyst

For many years, the mathematics faculty was frustrated by students' lack of retention of material from prerequisite courses, particularly skills learned in the calculus sequence as well as algebraic skills. This escalating level of frustration over poor student retention of prerequisite course materials finally reached a level of intensity such that it became the catalyst for our project *Calculus Readiness Assessment and Remediation using Maple T.A.*

First Steps

An initial proposal to correct this situation had three broad components: first, create "Core Topics Lists for Calculus I, II and III" [1]; second, research available technology and make a choice, and third, obtain funding to support our efforts.

- Step One: Create "Core Topics Lists for Calculus I, II and III"

During the 2002-2003 academic year, the Calculus Committee, chaired by Dr. Keating, set up core curricula for *Calculus I, II* and *III* to help alleviate inconsistencies from one instructor to another. Each of the core curricula is made up of two parts: a listing of basic content-specific topics to be presented by all faculty teaching calculus courses and a proficiency listing of required student technology skills. These requirements are course-appropriate to *Calculus I, Calculus II* or *Calculus III.* Each of entry exams and related tutorials are based on the listing of these content-specific topics and technology skills.

- Step Two: Research Available Technology and Make a Choice

In 1993, the Department incorporated the use of *Maple V*, a powerful computer algebra system, in the calculus sequence courses. In the 2002-2003 academic year, the Department required TI-89 graphing calculator technology in *Calculus I* and *II* as a way to assist our students to transition to the use of *Maple 10* in *Calculus III.* As you can see, there is a resident familiarity with *Maple* and expertise in its use within the Department.

Research of various technologies resulted in the selection of *Maple T.A.* "*Maple T.A.* has the full power of the advanced mathematical software *Maple* behind it. *Maple* has the ability to represent and solve problems in precalculus, calculus, linear algebra, abstract algebra, vector calculus, statistics, number theory, group theory and more. The powerful *Maple* engine can determine mathematical equivalences and automatically grade the student response appropriately. Like a human teaching assistant, *Maple T.A.* will detect when the response is equivalent to the programmed answer, instead of doing a mindless simple comparison. *Maple T.A.* can display *MathML*, so all your equations look the same as they do in your textbook. Students can use palettes and a math expression editor with free-form input, so they can enter their responses in the same way they would write them

[1] Available upon request.

down. To simplify entry, a graphing calculator is available. The student then has the option of previewing the equivalent 2-D expression before submitting his or her response. *Maple T.A.* includes built-in unit support for many common types of measurement. Equivalent answers are graded correctly. For more obscure measurement systems, *Maple T.A.* can be programmed to evaluate the problem. *Maple* has an extremely thorough coverage of units."[2] Of course, familiarity with *Maple* also was a factor in the decision to choose *Maple T.A.*

- Step Three: Obtain Initial Funding

The use of this technology would make our endeavor viable. However, the cost of purchasing *Maple T.A.* was not insignificant. Therefore, to obtain funding it was necessary to write grant proposals.

In February 2004, the grant *Computer-Based Remediation Modules: Algebra Through Calculus* (co-PIs: Davis and Keating) was funded by the Fund for the Improvement of Post Secondary Education (FIPSE) through the CSU system. With these grant funds, we were able to purchase *Maple T.A.* with which we could do online testing, evaluation and grading. The purchase of software consumed most of the grant funds; however, with the balance we were able to fund a very limited amount of time [one month] to begin to familiarize ourselves with *Maple T.A.*, draft sample questions for an entrance exam, and create a prototype for a tutorial on one calculus topic. Because we purchased *Maple T.A.* when it was first released, we found that the learning curve was steep. The online help, many telephone calls, and emails to the *Maplesoft* Technical Support Staff were our only resources. However, in time, some tutorials were created and made available. We are pleased to state that additional *Maple T.A.* materials and support are much more abundant and available now.

Progress Toward A Solution

Continuing with the work in assessment, we received funding during 2004-2005 from a CSU Learning Assessment and Improvement Grant for our proposal *Mid-Level Assessment of the Mathematics Program: Computer-Based Assessment of the Calculus Sequence* (co-PIs: Davis and Keating). Under this grant, we developed and pilot tested a *Calculus II* online entrance exam. The entrance exam had two parts: Part I tested the content-specific topics and Part II tested technology skills. We also developed a mandatory online tutorial for students failing this entrance exam. However, due to technical difficulties that required the University to purchase a dedicated server for *Maple T.A.*, we were unable to pilot the tutorial. The server was purchased and up and running by 2005.

During 2005-2006, with funding from a second CSU Learning Assessment and Improvement Grant for our proposal *Mid-Level Assessment of the Mathematics Program:*

[2] http://www.maplesoft.com/products/mapleta/advantage.aspx

Computer-Based Assessment of the Calculus Sequence, Part II (co-PIs: Davis and Keating) we completed and implemented fall semester 2005 entrance exams for Calculus II and Calculus III. We also implemented preliminary versions of tutorials for students who failed these exams. Unfortunately, we again struggled with technical difficulties, this time related to ECSU's network/firewall. At times, students were not able to read the hints embedded within tutorial questions because ECSU's firewall intermittently blocks these images. In addition, we have started analyzing data available from *Maple T.A.*, which tracks student performance as they take the entrance exams or work through the tutorials.

Implementation of entrance exams for fall semester 2005 had an immediate effect on student behavior. Students reviewed during the first week of class before taking the entrance exams. Moreover, our assessment policy states that students who failed an entrance exam are required to complete the corresponding tutorial before receiving a grade for the course. Students who do not complete the entrance exams or the tutorials receive a course grade of "Incomplete". In fall semester 2005, we had almost 100% compliance with our policy. The lone student who did not complete the mandatory tutorial received a grade of "Incomplete"; however, the tutorial was completed at the beginning of the next semester and the student received the earned course grade.

Preliminary analysis of data uncovered a weakness in our calculus program—students were not adequately prepared for success in Part II, the technology portion of the entrance exams. Mathematics faculty will address this instructional deficiency in our calculus sequence beginning fall semester 2006.

Future Plans

During 2005-2006, the mathematics faculty identified students' weak algebra skills as hampering student progress in more advanced courses, including the calculus sequence. The Mathematics Subgroup of the Department proposed adding a *Calculus I* entrance exam that would test precalculus material with heavy emphasis on algebra skills. In addition, the Mathematics Subgroup suggested adding questions that require various degrees of algebraic manipulation to the entrance exams for *Calculus II* and *Calculus III* and to the corresponding tutorials.

In 2006, we submitted a third CSU Learning Assessment and Improvement Grant proposal, *Mid-Level Assessment of the Mathematics Program: Computer-Based Assessment of the Calculus Sequence, Part III* (co-PIs: Davis and Keating). This proposal seeks funds to develop and implement an entrance exam and tutorial for *Calculus I,* and to revise/reformat the existing entrance exams and tutorials for *Calculus II* and *III.* Funding of the CSU Learning Assessment and Improvement Grants for 2006-2007 will be announced on May 24th of this year.

Our overall goal is to expand the vision of the Mathematics Program to include assessment of students' algebraic skills a well as their retention of calculus skills and concepts. Our plan includes remediation for struggling calculus students.

Outcomes

Publicizing the entrance exams among students has sent a strong signal to students that it is their responsibility to review prior to the first day of class. Faculty assigned to teach calculus courses have noticed that students have entered *Calculus II* and *Calculus III* with far more serious attitudes than in past semesters. After completing the exam, students get immediate feedback on how well they have done in their preparation leading up to the exams. In addition, faculty receive precise information on the areas where students are deficient and that information can be useful in planning classes. Since material from the calculus sequence serves as a cornerstone for the Mathematics Program, adding assessment at this level benefits the entire program. We expect the continuation of our work in assessment will lead to dissemination of information through other presentations and papers.

Conclusion

The catalyst for "Calculus Readiness Assessment and Remediation Using *Maple T.A.*" was the escalating level of frustration on the part of mathematics faculty over poor student retention of prerequisite course materials. Core topics for calculus-sequence courses were created and served as the basis of the online entry exams and the tutorials. Writing grants provided a means of obtaining funding to support our efforts.

The calculus portion of the grant *Computer-Based Remediation Modules: Algebra Through Calculus* provided funding for the purchase of a site license for *Maple T.A.* software, time to begin learning how to use *Maple T.A.*, time to develop preliminary (very rough) draft of one entrance exam, and time to create a rough prototype of a computer-based tutorial on one calculus topic.

The 2004-05 assessment grant, *Mid-Level Assessment of the Mathematics Program: Computer-Based Assessment of the Calculus Sequence*, provided funding to develop and implement an entrance exam for *Calculus II,* to create a draft of a tutorial for *Calculus II* students, and to solve technology problems: purchase and set-up of new server and solving problems of remote access.

The 2005-06 assessment grant, *Mid-Level Assessment of the Mathematics Program: Computer-Based Assessment of the Calculus Sequence, Part II,* provided funding to complete and implement entrance exams for Calculus II and Calculus III, to complete and implement first drafts of tutorials for Calculus II and Calculus III, to attempt to solve technology problems associated with ECSU's network/firewall, for preliminary analysis of the results and time to plan a Departmental response to our findings.

If funded, the 2006-07 assessment grant, *Mid-Level Assessment of the Mathematics Program: Computer-Based Assessment of the Calculus Sequence, Part III,* seeks to continue and add to the work accomplished in the previous three grants.