

EXPLORATORY ONLINE ASSESSMENTS OF COLLEGIATE DEVELOPMENTAL
MATHEMATICS AND SECONDARY LEVEL ALGEBRA COMPREHENSION:
A PILOT INITIATIVE

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ABSTRACT

This paper is a report on the status of our Pilot Initiative: *Exploratory Online Assessments of Collegiate Developmental Mathematics and Secondary Level Algebra Comprehension*. The 2009-2010 academic year was devoted primarily to planning with online testing of students enrolled in two sections of Elementary Algebra in spring 2010 and analysis of results of a *Maple T.A.* practice placement test administered to high school students.

INTRODUCTION

In *The Final Report of the National Advisory Panel*, which was commissioned in 2008 by the United States Department of Education, the members of the National Advisory Panel found that “A strong grounding in high school mathematics through Algebra II or higher correlates powerfully with access to college [and] graduation from college”.¹

At Eastern Connecticut State University, we have observed that increasingly students are graduating from secondary schools with poor skills in algebra; these poor algebraic skills, in turn, negatively impact their success in their university courses. Initially, Mathematics Faculty at Eastern perceived this problem solely as an “American problem”; however, through discussions with European educators, we discovered that they too are experiencing this same phenomenon. We note that our European colleagues have freely shared some of the actions they have taken to deal with student deficiencies in algebra.

¹ <http://www.ed.gov/about/bdscomm/list/mathpanel/report/final-report.pdf>

Determined to try to correct this problem at Eastern, at least in part, we submitted a proposal to the Connecticut State University System (CSUS) Universities Assessment of Learning for Educational Improvement Grant Program and received funding. Our goal was to assess and improve students' algebraic skills in courses within the Developmental Mathematics Program and to create a Pilot Initiative which would identify possible partnerships with Secondary-level teachers/systems in Connecticut in the 2010 – 2011 academic year. Securing these partnerships would enable us to assess/improve algebra skills for students both at participating high schools and also for those admitted to Eastern in an effort to reduce the percentage of incoming students who place into developmental mathematics courses.

PROJECT OBJECTIVES AND DESIGN

The learning, goals and/or outcomes addressed in this project were:

- To develop/implement a plan to form partnerships with secondary schools in Connecticut in order to create a dialogue among educators and to initiate a Pilot Initiative of online assessment of secondary-level student algebra skills.
- To identify and address algebra deficiencies of students *before* they are admitted to Eastern (or other universities).
- To model three existing partnerships: (1) Joining Mathematics Education (JEM) and secondary schools in the European Consortium, (2) Texas A&M University and Texas secondary schools, and (3) the Bridges Program at Eastern Connecticut State University.
- For the online assessment of secondary-level algebra skills, to build, with some modifications, upon a model used for our Online Mathematics Assessment System²; this model consists of course entrance exams and required tutorials for students who fail the entrance exams.
- To assess and improve students' algebraic skills in courses within the Developmental Mathematics Program at Eastern and with future partnering secondary schools.
- To disseminate our findings through conference presentations and publications in refereed journals.

² Based on our original online Calculus Assessment System.

ASSESSMENT INSTRUMENTS AND/OR METHODOLOGIES USED OR DEVELOPED:

Maple T.A., the software used to create and administer the entrance exams, tutorials and algebra modules/assignments, contains powerful data collection and analysis features. The analysis process for the proposed assessment was a modified version of our current Calculus Assessment System. During each academic year, data generated by the Calculus Assessment System is analyzed in the period between fall and spring semesters and also during the summer; the results are presented and discussed at subsequent Mathematics Subgroup meetings. The slight modification to our existing assessment process was to share Developmental Mathematics student results and secondary school algebra results with partnering teachers/secondary schools. Based on the results of the analyses, the Mathematics Faculty and partnering secondary schools each were expected to discuss ways to improve pedagogy, adjust curriculum or suggest improvements to the assessment system. The plan was to implement suggested improvements/curriculum adjustments during the following academic year.

FRAMEWORK OF OUR PROPOSED PILOT INITIATIVE

Joining Mathematical Education (JEM) and Secondary Schools in the European Consortium

“The Joining Mathematical Education (JEM) network has grown out of the previous OpenMath Thematic Network which produced the OM2 standard and initially was conceived as a way to promote semantic markup in the e-learning user community. The stated goal of the network is to bring into contact the major players in the area of educational mathematics on the web. This includes experts in technology development, authors of content and users. The JEM network goals are to contribute to content enrichments, to work towards commonly adopted and supported standards, and to disseminate end-user information. JEM’s projects are funded by the European Consortium.

The JEM network comprises about 20 nodes, some are founding members and some are associated members which were incorporated after the start. The network has been officially closed to new members but is considering new modalities in order to allow JEM to grow. The coordinator node is the University of Helsinki and among the partners there are two software companies, several universities (both technical and non-technical), some teacher education institutes and virtual universities. In Italy there is Liguori Editori and in total about 10 countries are covered, excluding the coverage provided by the European Math Society.”³

³ www.jem-thematic.net

While there are many worthwhile projects conducted by members of JEM, we were particularly impressed by a project conducted by Johanna Lehtinen, a member of the Department of Mathematics and Statistics at the University of Helsinki. In her paper, *Web-Based Teaching in Secondary School Mathematics* (found on the JEM web-site), Professor Lehtinen describes an approximately two-month study of two student groups, “control” versus “experimental”, in a Finnish secondary school. The purpose of the study was to determine whether or not additional web-based exercises improved student learning. Both the control group⁵ [traditional learning methods] and the experimental group⁶ [web-based learning methods] used the same textbook and were assigned exercises using the designated methodology. Both groups were administered similar pre- and post-tests. A typical online interactive question (created using *Maple T.A.*) for the experimental group is shown in Figure 1.

Question 1: (1 point)

Simplify

$$5 + (-27) - 8$$

Number

Figure 1: Student Web-Based Exercise

Initially, members of the control group performed slightly better than members of the experimental group; however, this was not the case at the end of the two month experiment. In the pre-test the average points of the experimental group was 20 and the average points of the control group was 20.53. In the post-test average points of the experimental group was 21.63 and the average points of the control group was 19.54. The maximum number of points in both tests is 25. The results of standardizing the control group’s average points in both the pre- and post-tests to a basis of 100% first and then standardizing the experimental group average points from that appear in Figure 2.

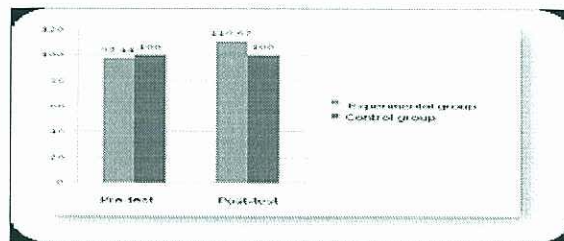


Figure 2: Comparison of web-based learning and traditional learning

⁴ johanna.lehtinen@helsinki.fi

⁵ 19 students in the control group

⁶ 15 students in the experimental group

Professor Lehtinen concludes that “according to this study web-based exercises improve the learning results in the secondary school. Interactive and web-based exercises and programs should be invested when making plans for improving education in the future.”

As a member of JEM, Dr. Salvatrice Keating had access to Professor Lehtinen’s paper and many others. We concur with Professor Lehtinen’s conclusions. In fact, we have observed at Eastern that students often prefer online access and practice to books in print and practice sheets. For this reason, Eastern’s Pilot Initiative was designed, in part, on the model presented in Professor Lehtinen’s paper.

Texas A&M University and Texas Secondary Schools

Another member of JEM, Professor G. Donald Allen, Department of Mathematics at Texas A&M University, is actively reaching out to secondary schools in Texas forming University - Secondary School partnerships to assess and improve the mathematical skills of secondary school students. Professor Allen, in collaboration with L. Zientek, M. Griffin, G. White and P. Wilhite, presented “College Algebra Across Texas – Survey Results” to the Texas Association of Academic Administrators in Mathematical Sciences in 2007. Thirty-three community colleges and thirteen universities participated in this survey.

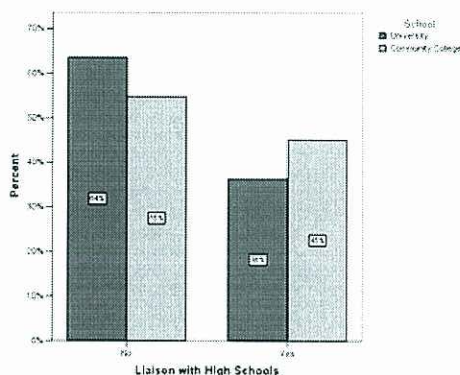


Figure 3: Percentage of Texas University and Community College Liaisons with High Schools

The chart in Figure 4 presents a table of topics that Department Chairs at Texas universities and community colleges rated in terms of level of importance for incoming College Algebra students.

Topics Indicated by Department Chairs as Important for Incoming College Algebra Students

Topics	Percent by University			Percent by Community College		
	Most Important	Somewhat Important	Marginal or No Importance	Most Important	Somewhat Important	Marginal or No Importance
Algebraic Manipulation	100	0	0	100	0	0
Problem Solving	67	25	8	84	16	0
Fractions	83	17	0	82	16	0
Logarithmic/Exponential	18	55	27	16	68	16
Trigonometry	0	36	64	3	13	84
Regression Modeling	9	9	82	3	20	77
Graphing Calculator	18	55	27	6	47	47
Group Work	9	27	64	0	48	52

Figure 4: Topics Indicated by Department Chairs at Texas Universities and Community Colleges as Important for Incoming College Algebra Students

Professor Allen and his colleagues concluded that “College Algebra students were typically not entering STEM⁷ fields, university and community colleges were consistent in their beliefs about what topics students should know and algebraic manipulation and fractions topped their list. The predominant instructional method for both was traditional lecture, but graphing calculators were being incorporated in the lectures for some. Assessment was made using exams and quizzes, but courses alone were not used to predict students’ college readiness. University and community college mathematics departments were parallel on instructional modality, use of technology and assessment methods; neither has moved far from the traditional classroom.”

The Bridges Program at Eastern Connecticut State University

Four districts (Windham, Norwich, Killingly, and Windsor) joined Eastern Connecticut State University Education and Mathematics Faculty in a partnership, *Mathematical Modeling: A Bridge to Secondary and College Mathematics*, to increase student achievement through increasing teacher content knowledge and skills in the use of math modeling strategies, data collection, data analysis and instructional planning to improve teaching and student learning.

⁷ STEM : Science, Technology, Engineering, and Mathematics

Developmental Mathematics Program/Bridges Program

During 2009-2010, as part of Eastern's Pilot Initiative, which was designed to serve as a bridge between secondary-level mathematics and our Developmental Mathematics Program, we accomplished the following:

- An Elementary Algebra (MAT 098) Assessment Prototype was developed and implemented to assess the pre-algebra background of students enrolled in MAT 098 courses at Eastern.
- A *Maple T.A.* practice placement exam was developed. This exam had a high correlation with ACCUPLACER results. One advantage of the *Maple T.A.* practice placement exam was the capability of question by question analysis that could be shared with secondary teachers.
- In fall 2009 two sections of MAT 098 were assessed and students in three algebra classes participating in the Bridges Program were assessed. Data (grades and related statistical analysis, exam item statistical analysis etc.) were reviewed and discussed with both Mathematics Faculty at Eastern and participating secondary school teachers.
- In spring 2010 two sections of MAT 098 were assessed. Data (grades and related statistical analysis, exam item statistical analysis etc.) were reviewed and discussed with the Adjunct Faculty (secondary school teachers) responsible for one of the MAT 098 sections.
- In spring 2010, an additional participating secondary school teacher/system has agreed to be part of our Pilot Initiative efforts in 2010-2011 and a different participating secondary school has been identified, but has not yet formally committed to date.
- The assessment system sent a strong message to students that they were responsible for improving their algebra skills through practice. When given the chance, students were up to this challenge. Furthermore, information learned from the assessments helped secondary school teachers determine areas in which they should concentrate efforts in order to shore up student weaknesses as well as areas where they need not spend as much time. This should lead to more efficient use of classroom time.

ANALYSIS PROCESS

The analysis process for the proposed algebra assessment system followed the "Eastern plan" implemented for the Precalculus, Calculus Sequence and Developmental Mathematics Assessment Systems. This included question-by-question analysis to identify areas of strengths and weaknesses as well as examination of samples of

individual entrance exams and tutorials in order to better understand specific types of errors. As mentioned earlier in this paper, these results were shared (and will continue to be shared as new results are available) with Mathematics Faculty and were used to implement future modifications to the curriculum, improved pedagogy, and refinement of the Assessment System. Each year after improvements have been implemented, the cycle begins again the following year. We expect that this process will be similar for participating secondary school teachers and their districts.

A DESCRIPTION OF THE ANALYSIS OF THE ASSESSMENT INFORMATION USED

To prepare for the Developmental Mathematics Assessment Instrument, we created a list of core pre-algebra topics, which included skills students would need in order to be successful in Elementary Algebra, MAT 098. A MAT 098 Assessment Prototype entry exam was developed and implemented in spring 2010. The entry exam was administered to students enrolled in two sections of Elementary Algebra, MAT 098, and results were analyzed. Even though mean student scores in the two sections were reasonably high, 87% and 79%, respectively, we learned through item-by-item analysis of student responses that MAT 098 students have weaknesses in pre-algebra skills that include translating a word expression into an algebraic expression, order of operations, raising a negative number to a power, and operations with fractions.

Areas of weakness identified through our assessment were shared with Adjunct Faculty (secondary school teachers) who were assigned MAT 098 as well as Mathematics Faculty. This practice will continue in the next phase of our Pilot Initiative with those teachers and secondary schools who choose to partner with us in the 2010 – 2011 academic year.

In working with area high school teachers in the Bridges Program prior to the implementation of our Pilot Initiative, we discovered several topics contained on college mathematics placement exams that had been omitted from the high school curriculum. Two examples include factoring a trinomial and application of the quadratic formula. Teachers adjusted their curriculum to accommodate the missing material. In our Pilot Initiative we communicated with partnering teachers before creating the Maple TA practice college mathematics placement exams and thus incorporated their ideas into the exam. This also gave us an opportunity to share with participating teachers sample problems from a variety of placement exams.

In the analysis of individual answers on the Calculus I and Precalculus entry exams, we found several cases where students incorrectly squared a binomial. For example, the error $(5x - 6)^2 = 25x^2 + 36$ showed up on several exams. Another area of concern involved fractions – any type of problem with fractions! Additional questions involving fractions will be added to next fall's assessment exams.

DISSEMINATION

Our 2009-2010 work on assessment and our proposed Pilot Initiative was disseminated at two conferences:

- The Twenty-Second International Conference on Technology in Collegiate Mathematics (ICTCM) (held March 2010 in Chicago, Illinois).
- The Connecticut State University Assessment Conference (held April 2010 at Central).

SIGNIFICANT PROJECT OUTCOMES, IMPROVEMENT STEPS AND FUTURE WORK

What was learned from the project?

From earlier analysis of data, we learned that algebraic weakness negatively impacts students enrolled in all the mathematics courses offered in Eastern's major and service courses. Students continue to struggle with very basic algebraic problems, such as simplifying an algebraic fraction or finding the equation of a line given two points on the line (particularly if fractions are involved!). The forced review of prerequisite material (by entry exams or tutorials) has helped students progress through their mathematics courses.

Although we will continue working to address students' algebraic weaknesses at the college level, we feel that it is beneficial to focus on the high school level as well. If student deficiencies in algebra can be addressed at the secondary school level, then that should remedy mathematical weaknesses due to poor algebra skills at the university level.

What improvements are proposed to enhance student learning?

- Inclusion (in 2010-2011) of the model implemented by Johanna Lehtinen at the University of Helsinki is proposed as a supplement to our 2009-2010 Pilot Initiative.
- Implementation of "Bridges-type" programs with identified participating high schools will begin in 2010-2011.
- Revision of mathematics course content at Eastern to include materials that address current student deficiencies will be implemented.
- Creation of online practice sessions using *Maple T.A. 6.0* available on the Mathematics Department Web site is under consideration.

What improvements are proposed to enhance the assessment?

There were problems with the upgraded Maple TA 5.02 software this semester; it was necessary to reboot the system several times, there were instances where students' exams or tutorials froze or where students completed the assessment but we had to force grade the assessment. These problems were reported to representatives of MapleSoft, Inc., and they are working with us to correct them. *Maple T.A. 6.0* has just been released and will be installed on the Department server in June 2010. During the summer of 2010, we plan to test, with the help of Mathematics Department student workers, the online exams and tutorials using this latest version and to make modifications, if necessary. Hopefully, this will prevent technology "glitches" next fall.

Future efforts will include online assessment modeled on the Student Retention of Prerequisite Mathematics Knowledge Online Assessment Program currently in place at Eastern and also practices utilized by JEM (Johanna Lehtinen) at the University of Helsinki and Texas A & M University (G. Donald Allen), which involves an online pre-test, online tutorials, and an online post-test of participating secondary school students using *Maple T.A. 6.0*.

Other areas of learning that need to be addressed

Students are beginning to take deadlines for the placement exams and tutorials seriously. This past year only a handful of students requested deadline extensions. Getting students to take responsibility for their own learning has been a challenge – but it appears to be paying off.

We need to address the deficiencies in students' ability to use the TI-89 calculator for types of problems included in the Department's technology proficiency Assessment Exams. One possibility is to give calculator tutorials in the Eastern's Mathematics Achievement Center (MAC) or to create and place "practice assessment" on the Department web site. We will consider this for the next academic year.