3

ALEKS-based Placement at the University of Illinois

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3.1 Introduction

ALEKS is an adaptive assessment and learning mechanism used as a course companion and assessment tool. The use of ALEKS as an assessment mechanism in higher education at the level between college algebra and calculus began recently, following the work of Carpenter and Hanna which showed that ALEKS could serve as a preparedness measure (Carpenter and Hanna, 2006). This chapter investigates the use of ALEKS as part of a placement mechanism at the University of Illinois, comparing the results to the previously used mechanism based on ACT scores. The effectiveness of standardized college entrance exams as predictors of student performance has been previously investigated, particularly for the SAT (Baron and Norman, 1992). An ALEKS-based mechanism has been implemented at Boise State University (Bullock et al., 2009), using ALEKS as a course companion and as an assessment mechanism. Emulating the implementation at the University of Illinois, the Boise State Mechanism has had similar results regarding the decline of failure proportions in placement courses and enrollment changes. Other studies investigate the use of ALEKS as a course companion (Hagerty and Smith, 2005; Hampikian et al., 2006; Hampikian, 2007; Callahan et al., 2008; DeLucia, 2008, see also Chapters 4 and 5 in this volume). For more information regarding the implementation details of ALEKS see Falmagne et al. (2006) or Falmagne and Doignon (2011).

Ineffective course placement has many negative effects. Students may face significant consequences for failure or withdrawal from a course, in addition to increasing time towards degree completion, because they do not recognize the risk of failure until the first midterm examination (generally four weeks into a semester and two weeks past the add-deadline). At the University of Illinois, the standard introductory calculus course (Calc: Calculus I) is a five credit course, the withdrawal from which beyond the add-deadline may reduce students to a credit total below full-time status, resulting in the loss of tuition benefits, health benefits, scholarships, and athletic eligibility.

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Improper course placement also results in students being taught material they already know or are unprepared for and introduces challenges for advisors and faculty, including course planning. Poor course performance from overplacement may lead to forced change of major and academic probation. A loss of time from underplacement may force the student to stay an additional semester, incurring substantial additional financial costs.

3.2 Placement at the University of Illinois

The Department of Mathematics at the University of Illinois at Urbana-Champaign, at the impetus of the first author, began searching for a cross-platform web-based assessment and placement instrument in October of 2005. Placement at the University of Illinois at that time was based on ACT scores. The Mathematics department desired a new placement mechanism that would reduce the high failure and withdrawal rates in many of the introductory mathematics courses.

Several reasons were proposed for the high failure rates. Students at the University of Illinois come from a variety of geographic locations and educational backgrounds. High school students in the state of Illinois are only required to take three years of mathematics courses. Many students elected not to take mathematics in their final year of high school and may have forgotten significant amounts of mathematical knowledge in the more than a year that passed before they arrived at the university. Moreover, the indicators of a student's mathematical knowledge and skill – their high school transcript and standardized test scores – were captured at the height of their knowledge rather than at the time of course enrollment.

Many examinations and systems were evaluated and piloted. ALEKS was chosen because of its ability to measure students' knowledge and the facts that it is cross-platform (requiring only a web-browser), non-multiple choice, and adaptive. The assessments provided by ALEKS were then used as a basis for a placement mechanism under the assumption that the initial knowledge of a student, measured shortly before entering a course, would be predictive of student success.

3.3 The University of Illinois Math Placement Program

In the summer of 2007 the University of Illinois Department of Mathematics began using ALEKS to assess students for course readiness. The placement program focuses on four courses: Preparation for Calculus (Math 115: **PreCalc**), Calculus I (Math 220: **Calc**), Calculus I for students with experience (Math 221: **CalcExp**), and Business Calculus (Math 234: **BusCalc**)[3].

[3]For a description of these courses, please see:
http://courses.uiuc.edu/cis/catalog/urbana/2007/Fall/MATH/index.html .

The placement program was required for course placement by the mathematics department for all students enrolling in the focus courses and became a university requirement for all incoming students in 2008.

3.3.1 Assessment Procedure. The placement exam is an ALEKS assessment composed of items from the "Prep for Calculus" course product, slightly customized to remove some items that do not appear in the syllabi of the focus courses at the University of Illinois. Students access the assessment in a non-proctored setting such as their homes or a campus computer lab. Students who fail to reach the required score for placement for a particular course have the option of retaking the placement exam or self-remediating using the ALEKS learning module (and other methods of their volition). Students are allowed to repeat assessments during the five months prior to the course add-deadline, which is always the fifth day of enrollment. Students that ultimately take another course in the placement pool must take another assessment regardless of the grade obtained in a prerequisite course.

3.3.2 Determination of Placement Cutscores. Data were also collected the previous semester by offering students a small grade incentive (to ensure proper effort) in the focus classes, providing initial cutscore choices. These were lowered slightly for the first year of implementation to 40% for BusCalc and PreCalc and 60% for Calc and CalcExp to account for any bias in the initial testing procedure. After the first year of data collection the cutscores were raised to 50% and 70%, scores indicated by the data to be more effective in reducing overplacement.

3.3.3 Policy Enforcement. In the first year, the placement policy was enforced by making ten percent of the student's final grade contingent on completing the ALEKS requirement, all or nothing. The remaining 90% of the grade was calculated based on homework, quizzes, and exams (depending on the teaching style of the instructor). In the subsequent year is was possible to make the placement exam a prerequisite (in fact the only prerequisite) for enrolling in a course.

The policy change emphasized the positive role of assessment for the students, by providing an accurate and current assessment of their skills to them and to the mathematics department. For many students, the ALEKS assessment may have been the first objective evaluation of their mathematical skills that they had received in years (or ever).

3.4 Description of the Data

The data consist of the following information for each student in any of the focus courses for which an ALEKS assessment is required, for each semester in which the policy affects (Fall 2007, Spring 2008, Fall 2008):

1. enrollment and grades (including withdrawals) reported as
   A+, A, A−, B+, B, B−, C+, C, C−, D+, D, D−, F, or W;
2. ALEKS assessment reports for all assessments completed, including subscores, with scores as percentages;
3. ACT Math scores.

Some students enrolled in more than one course during the three semesters. The total number of assessments exceeds 15,000 for approximately 10,000 students. Approximately 20% of the students took more than one assessment (see Figure 3.1).

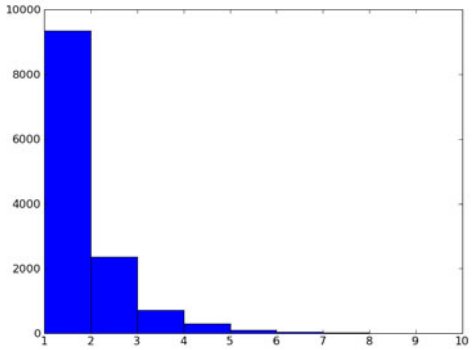

Figure 3.1. Histogram of ALEKS Assessments per student: Most students took a single assessment from which their placement was determined. Around 20% took a second assessment, and relatively few students took three or more assessments.

3.4.1 Histograms of ACT and ALEKS scores. Visualizations and basic statistics of these data are given in the figures below. The legends contain the mean and standard deviation for each course in Figures 3.2 and 3.3, which are normalized for direct comparison. Notice the bimodalities that emerge in the ALEKS histograms versus the single modalities of the ACT histograms. The authors believe the bimodality to result from the state policy of only requiring three years of mathematics in high school, but this hypothesis was not confirmed analytically.

In the first year of implementation, the cutoff scores for PreCalc and BusCalc was 40% and for Calc and CalcExp was 60%. In the second year of implementation, these scores were changed to 50% and 70%, respectively, based on analysis of the data from the first year. This is clearly evident in the distributions in Figure 3.3 when comparing the Fall 2008 scores to the prior two semesters.

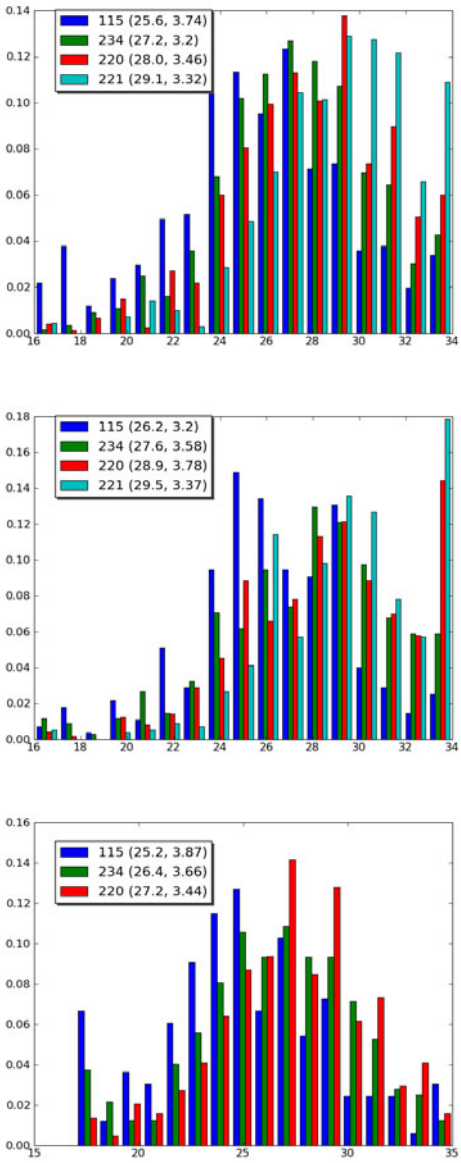

Figure 3.2. ACT Math Histograms, normalized. Top: Fall 2007. Middle: Fall 2008. Bottom: Spring 2008. Each bar shows, for the corresponding course (Math 115: PreCalc, Math 234: BusCalc, and Math 220: Calc), the proportion of students with a particular ACT Math score. In the more difficult courses, the means of the distributions are slightly larger, while the variances are largely similar.

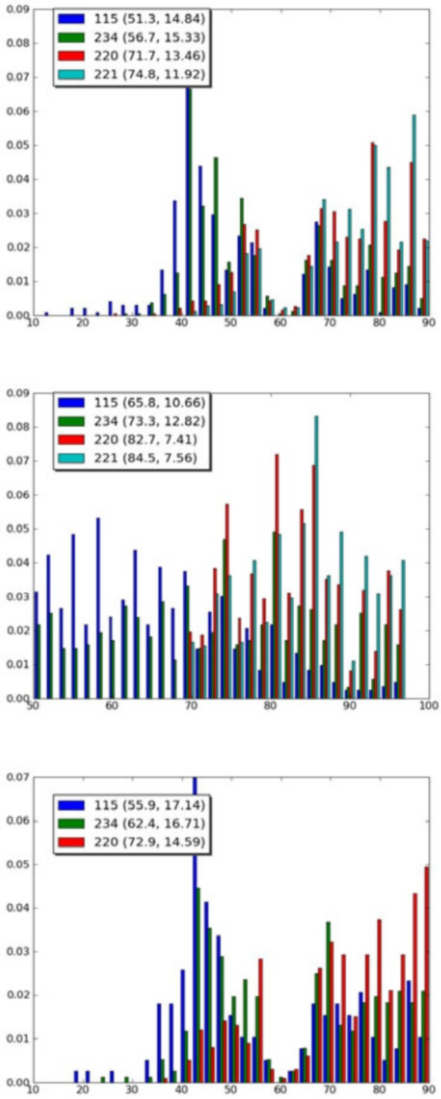

Figure 3.3. ALEKS Score Histograms, normalized. Top: Fall 2007. Middle: Fall 2008. Bottom: Spring 2008. Each bar shows, for the corresponding course (Math 115: PreCalc, Math 234: BusCalc, Math 220: Calc, and Math 221: CalcExp), the proportion of students with a particular ALEKS score in the corresponding course. There is an evident bimodality to the distributions, possibly because high school students in the state of Illinois are not required to take a mathematics course in their final year. In contrast to the ACT Math scores, the distributions are more separated. This is partially due to the fact that students were placed into these courses based on achieving a minimum score.

3.5 Analysis of Data

The focus courses had many instructors and teaching assistants each semester. Most of the students were in large lecture courses with weekly discussions, but some were in small discussion oriented courses or small lectures. No attempt was made to control for these factors in the grade data because the decision

to enroll in a particular style of course is not determined by any placement mechanism, rather by student preference in style or time of course meetings.

3.5.1 Effect of placement on DFW rates and enrollment.
A change in assessment policy affects the enrollments of the focus courses and those courses immediately in the sequence before or after focus courses. The relative enrollment changes (relative to Fall 2006 enrollments which are before the use of `ALEKS`) are given below. Note that Preparation for Calculus (PreCalc) was first offered in Spring 2007, and so Fall 2006 comparisons are not possible.

Lowering DFW (D+, D, D−, F, or withdrawal) percentages was a principal motivation for the placement program. In addition to providing information for advisors and department members to help students land in the appropriate course, `ALEKS` also provides students with a measure of their current mathematical skills. Many students may have been unaware of their relative lack of preparedness before completing an `ALEKS` assessment and subsequently altered their enrollments appropriately, but it is not possible from the data to determine how many students failed to meet their initial goal and enrolled in a prerequisite course.

The relative changes in fail (D+, D, D−, and F) percentages and withdrawal percentages are given in Tables 3.1 and 3.2. These tables reveal several changes to the distribution of students and final grades. In particular, withdrawals were dramatically reduced and enrollments shifted toward the more advanced courses. These percentages are compiled over all sections and instructors of the courses which were not consistent in the three relevant years. The proportion of students failing BusCalc was greatly reduced. In all four placement courses, the number of DFW students averaged in 2007 and 2008 was lower than in 2006.

Course	% Decrease W	% Decrease (D±, F)	% Increase Enrollment
BusCalc	57%	40%	-7%
Calc	49%	-12%	3%
CalcExp	67%	62%	21%

Table 3.1. Changes in Withdraw, Failure, and Enrollment for Fall 2007 relative to Fall 2006

Course	% Decrease W	% Decrease (D±, F)	% Increase Enrollment
BusCalc	19%	33%	-18%
Calc	81%	-16%	8%
CalcExp	42%	-0.7%	38%

Table 3.2. Changes in Withdraw, Failure, and Enrollment for Fall 2008 relative to Fall 2006

The withdrawal percentages for all courses dropped substantially relative to the fall semester of 2006, which is the last semester in which ALEKS was not used as a placement mechanism. This indicates that the placement mechanism reduced severe cases of overplacement, although there is a increase in the number of students receiving a score of D+ or below in Calc. Notice that enrollments changed significantly as more students placed into the calculus courses Calc and CalcExp or chose not to take BusCalc, a calculus course of less rigor, which is often not accepted in graduate programs in business as fulfilling the undergraduate calculus requirement.

3.5.2 Relationship of Placement Scores and Grades.
National standardized collegiate entrance examinations, such as the ACT and SAT, are generally taken by students in their junior year, providing a snapshot of student abilities at a time that is significantly prior to enrollment. A mechanism relying on an assessment with a temporal delay is a potential source of underplacement, in the case that the student completed additional mathematics courses after the examination date, and a potential source of overplacement, in the case that the student's skill level decreased from lack of use.

The ALEKS distributions provide more granular information on the mathematical abilities of the students in the placement population than standardized tests. These scores can be interpreted as the percentage of concepts of prerequisite material known by the students rather than a renormalized national standardized test score, of which the meaning is less substantial. The placement program uses the total percentage of concepts demonstrated and does not incorporate subscores for specific content areas.

The distribution on the ALEKS plot in Figure 3.4 is increasing with grade in both the medians (the horizontal line within the box) and the interquartile range. Figure 3.5 shows the correlation between ACT scores and ALEKS scores with final grade. In the ALEKS plot, scores are aggregated over 5 point intervals (as in a histogram). The numbers near each point indicate how many scores contributed to the mean computation.

3.5.3 ALEKS Subscores. The ALEKS exam content is broken into several subcategories, listed in Table 3.3 on page 61.

Each subscore contributes to the overall correspondence between the ALEKS score and student performance, though there are dependencies among the subscores. For every course and every semester, the subcategories for functions and for trigonometry had the highest mutual information with the grade distribution. See Table 3.4 (also on page 61). The categories for rational expressions and radical expressions are also relatively large in proportion. The numbers category is relatively poor, which is explained by the fact that most students obtain complete or nearly complete mastery in this category. The

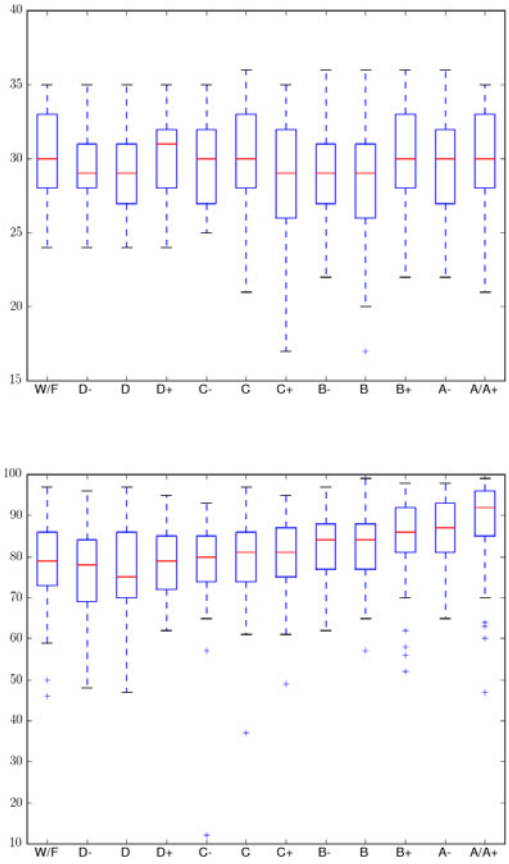

Figure 3.4. CalcExp Fall 2008: Box plots of grade distributions for ACT Math score (top) and `ALEKS` score (bottom). Notice that the medians (indicated by the central red lines) are relatively flat for the ACT Math score yet are increasing for the `ALEKS` score as grades increase. Similarly for the interquartile ranges (blue boxes).

logarithms and exponentials category is also relatively poor in proportion, for the opposite reason as most students performed weakly in this category.

That the information from the function subscore correlates highly with the grade distribution is not surprising since the content of the focal courses is heavily dependent on shifting and plotting functions, modeling using functions, and operations on functions, such as limits and derivatives. Interestingly, trigonometry has a strong subcategory correlation for BusCalc in the Fall 2008 semester despite the fact that trigonometry is not used in the course.

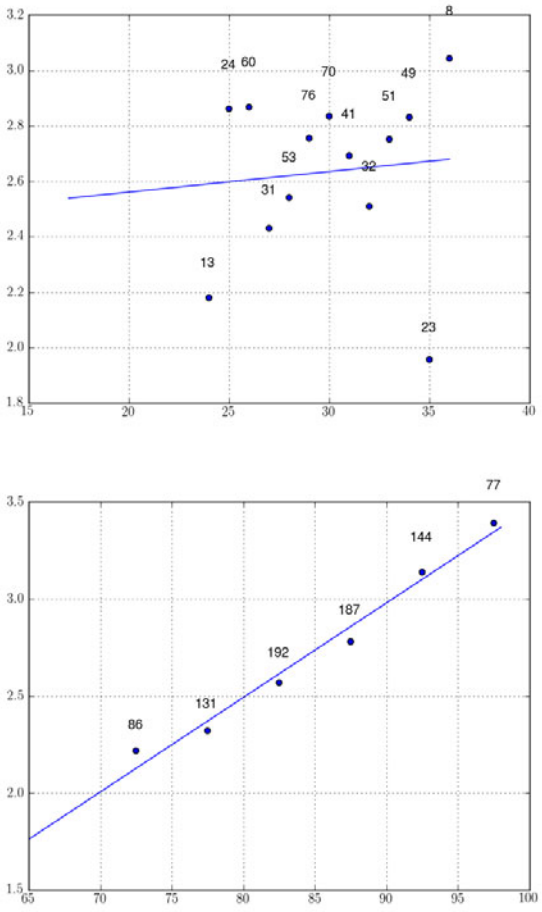

Figure 3.5. CalcExp Fall 2008: Mean Grade versus Exam Scores for ACT Math (top) and ALEKS (bottom). This plot reflects the behavior of the distributions in Figure 3.4. The ALEKS scores are grouped into buckets (width 5) and the points have a correlation coefficient of $r^2 = 0.97906$. Grouping scores did not substantially increase correlation coefficient of the ACT Math score $r^2 = 0.00895$.

The higher correlation may result from a relationship between trigonometric knowledge and mathematical maturity. See Figure 3.6.

3.5.4 Effect of Placement Policy on ALEKS Subscores.

Figure 3.7 (page 63) shows the subscore distributions for PreCalc in the fall of 2007, in which a soft requirement of 40% was used, compared to the fall of 2008, in which a hard requirement of 50% was used. Figure 3.8 is the same

Subcategory	Content	Items
Numbers	Real Numbers	23
Equations	Equations and Inequalities	29
Functions	Linear and Quadratic Functions	40
Polynomials	Exponents and Polynomials	26
Rationals	Rational Expressions	23
Radicals	Radical Expressions	21
Logarithms	Exponentials and Logarithms	17
Trigonometry	Geometry and Trigonometry	36

Table 3.3. `ALEKS` Assessment Subcategories. The total set of items in the assessment is partitioned into these subcategories.

Course	Semester	Total `ALEKS`	Functions	Trig
PreCalc	Fall 2007	0.461	0.239	0.240
PreCalc	Spring 2008	0.574	0.306	0.430
PreCalc	Fall 2008	0.310	0.173	0.142
BusCalc	Fall 2007	0.634	0.325	0.370
BusCalc	Spring 2008	0.472	0.222	0.231
BusCalc	Fall 2008	0.317	0.203	0.176
Calc	Fall 2007	0.660	0.433	0.341
Calc	Spring 2008	0.361	0.196	0.202
Calc	Fall 2008	0.166	0.102	0.097
CalcExp	Fall 2007	0.719	0.390	0.415
CalcExp	Fall 2008	0.156	0.081	0.096

Table 3.4. Proportion of grade distribution entropy captured by `ALEKS` score and subscores. Mutual information is a measure of dependence between two variables (Cover and Thomas, 2006). The subscores capture a significant portion of the total information captured by the total `ALEKS` score.

comparison for Calc, with cutoffs of 60% and 70%. The higher cutoff led to better prepared students, evident from the larger medians in each subscore.

3.5.5 ALEKS as a placement measurement tool. Students fail courses for many reasons that are difficult to determine simply from their placement scores and unrelated to their academic preparedness, such as negative housing situations (for instance due to randomly assigned roommates in dormitories), financial stresses, and poor time management. For incoming students the number of challenges is even greater. Accordingly, no assessment process is expected to predict student performance completely. Nevertheless, proper preparation is expected to be a factor in student performance and so correlation of the initial preparation measure and final grade performance is an indication of effectiveness. The data indicate that the `ALEKS` assessment re-

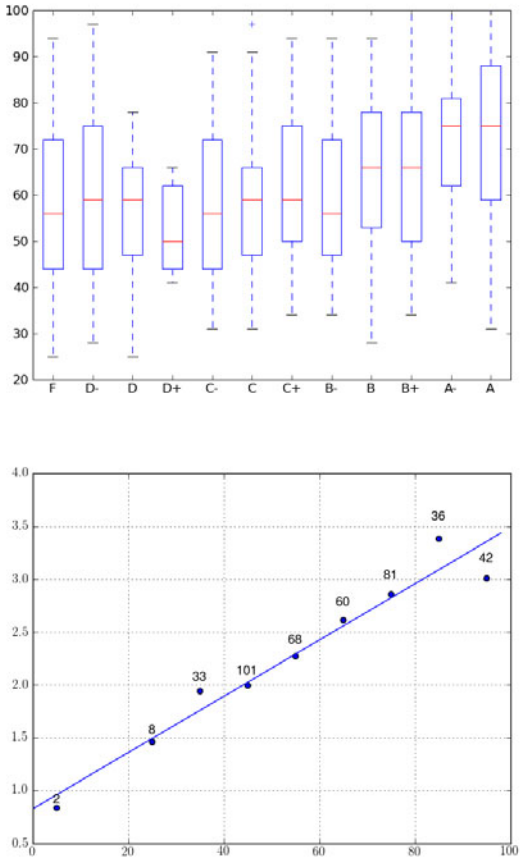

Figure 3.6. ALEKS Trigonometry Subscore, BusCalc, Fall 2008. Top: ALEKS Trigonometry Subscore (%) boxplots per Grade. Bottom: Trigonometry Subscore (%, width 10 buckets) vs. Grade Mean of bucketed scores (on 4-point scale), $r^2 = 0.94936$. The trigonometry and geometry subscore is clearly related to the final grade even though trigonometry is not used in the course.

port (using the aggregate score) correlates much more significantly than ACT scores (for instance, see Fig. 3.5). This is broadly true over all classes and semesters.

3.5.6 ALEKS as a preparation assessment tool. The core content of the placement exam mirrors the content in the PreCalc and so it is expected that ALEKS assessment scores will improve for students who successfully complete the Preparation for Calculus course. Because students are required to take an assessment to enter PreCalc and Calc, data are available for many students who progressed from PreCalc to Calc, taking assessments before and after the

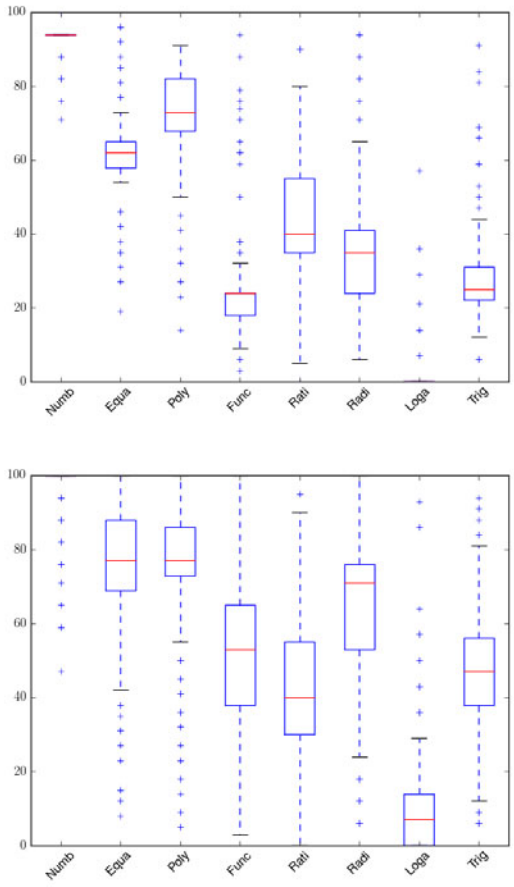

Figure 3.7. Effect of Policy change on Subscores in PreCalc. The vertical shift in every distribution between Fall 2007 (top) and Fall 2008 (bottom) is due to the higher placement requirement in 2007.

former course. The increase in ALEKS score for these students is shown in the Figure 3.9.

The 52.5% average relative improvement in assessment scores may be interpreted in at least two ways. Under the assumption that ALEKS accurately measures a student's state of knowledge, the improvement in assessment score indicates that the students who completed Preparation for Calculus learned a significant number of the concepts covered by the assessment. Conversely, assuming that the course effectively teaches students precalculus concepts, the improvement in assessment scores indicates that ALEKS is detecting the students' newly acquired knowledge.

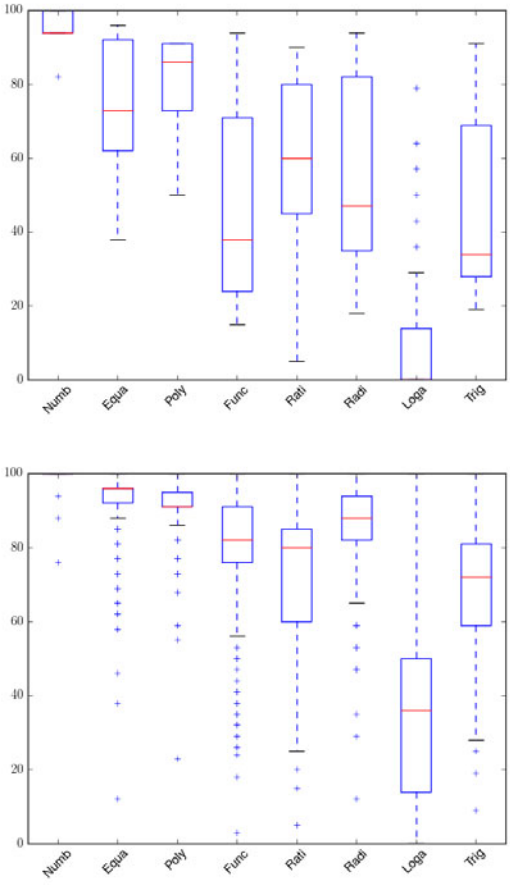

Figure 3.8. Effect of Policy change on Subscores in Calc. The vertical shift in every distribution between Fall 2007 (top) and Fall 2008 (bottom) is due to the higher placement requirement in 2007.

The improvement in student knowledge resulting in the successful completion of PreCalc is shown in Figure 3.10. Contrast with the incoming Calc students' abilities in Fall 2008 in Figure 3.11.

3.6 Discussion

The ALEKS-based mechanism used at the University of Illinois effectively reduces overplacement and is more effective than the previously used ACT-based

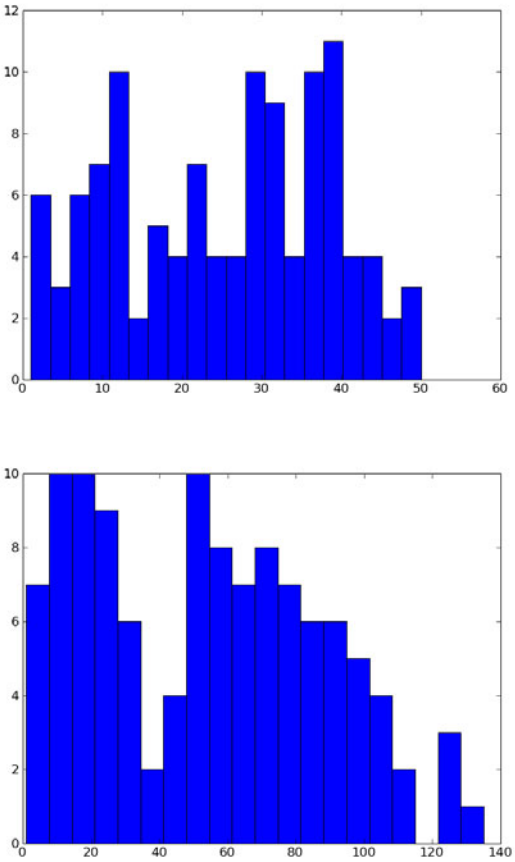

Figure 3.9. ALEKS Assessment difference Histograms for students passing through PreCalc to Calc. Top: Histogram of absolute differences in score. Bottom: Histogram of relative differences in score. Students passing through PreCalc into Calc in successive semesters had to retake the placement assessment. These students showed substantial increases in placement scores. Some students who took PreCalc could have already placed into Calc (if their score exceeded 70%), and so may not have improved much. Others went from $\approx 50\%$ to at least 70%

mechanism. Significant enrollment distribution changes occurred as a result of the mechanism implementation. These changes are similar to the emulation implementation at Boise State University. The use of ALEKS as part of placement mechanisms is justified by the data, noting that preparation is one component of placement and is not expected to be a complete predictor.

ALEKS assessments provide more specific skill information than the ACT. Correlations of ALEKS subscores with student maturity and performance meet

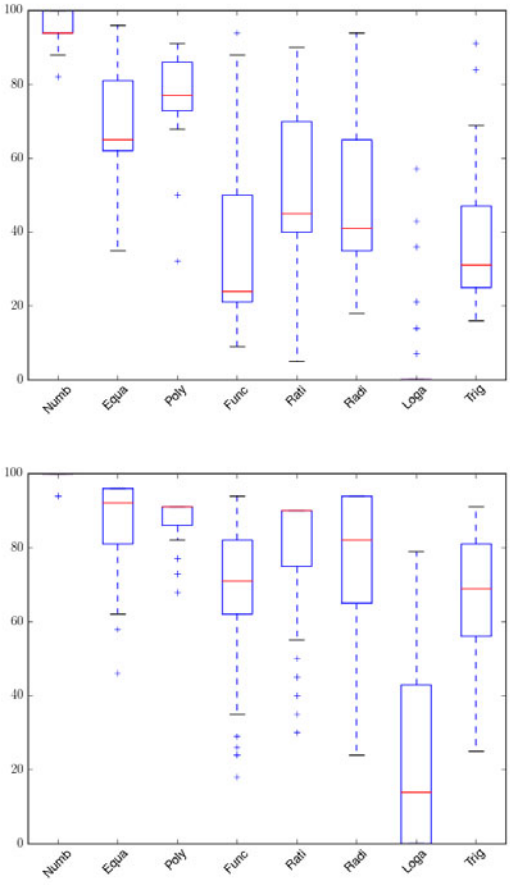

Figure 3.10. ALEKS Assessment Subscore differences from completion of PreCalc. Top: All assessments for the course for students before enrollment. Bottom: All students that subsequently enrolled in Calculus in the next semester.

expectations in many cases (all students in Calc in the Fall of 2008 had complete mastery of the most basic category), and reveal interesting characteristics of the student population in other (systematic weakness in exponentials and logarithms). ALEKS reveals skill bimodality in the population not captured by the previous placement mechanism which the authors believe is due to the high school math education policy of the state of Illinois. Specifically, mathematics is not a requirement for high school seniors in the state (of whom $\approx 90\%$ of the student body is derived), so many incoming students have not had direct exposure to mathematics in more than a year before enrollment.

The data show that preparation, as measured by ALEKS, correlates positively with course performance, and more strongly than the ACT in general.

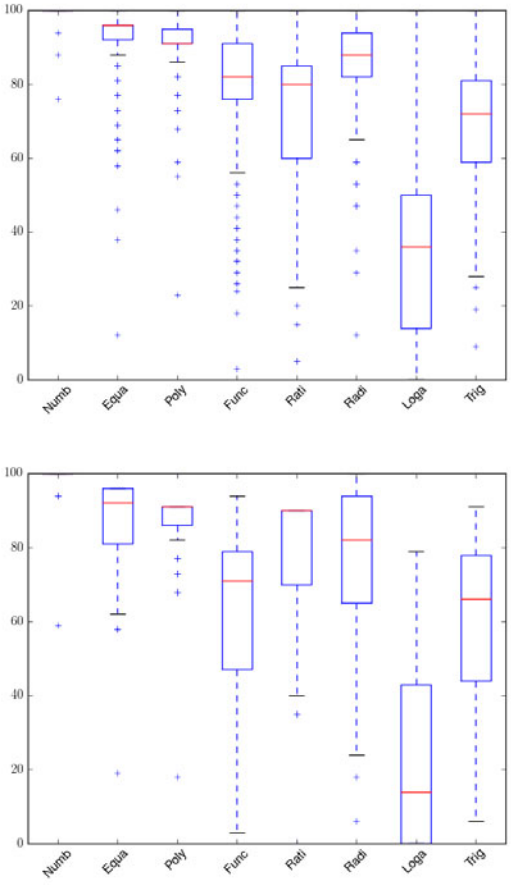

Figure 3.11. ALEKS Subscores for Calc, Fall 2008. Top: All Students. Bottom: All Students, excluding those from PreCalc.

Though a student may pass a course with a lower percentage of prerequisite concepts known, students receiving grades of A or B generally show greater preparedness. Longitudinal comparison of students taking PreCalc (Preparation for Calculus) shows that ALEKS assessments are an effective measure of knowledge increase. Calculus students with weaker skills can be brought to the skill level of their peers, as measured by ALEKS, by taking a preparatory course. Interestingly, the data provided by ALEKS provides a measure of course effectiveness when students' performance is aggregated and tracked longitudinally.

Policy changes in the second year of implementation improved the mechanism significantly and shows the need for consistent policy application that reduces student incentive to cheat. The results suggest the need for testing

all students in the placement population because of incidences of high ACT scores but low ALEKS scores and poor performance. Data needs to dictate the details of the policy, such as setting appropriate cutscores, for a more effective mechanism.

The installation of the ALEKS-based mechanism at Illinois has had many tangential outcomes. The data has been used to strengthen and improve the PreCalc curriculum. The data shows that students are improving in the PreCalc course, but that there are global weaknesses in exponential and logarithmic functions, as measured by ALEKS. This has led to a shift in emphases as less time is now spent on topics such as polynomial functions (students enter with high levels of proficiency) to allow for increased attention on exponential and logarithmic functions, a weak area not only for PreCalc students, but also for Calc.

The campus culture regarding lower division math courses has shifted for the better as students, advisers, faculty, and the administration recognize that effective placement is a benefit to all. Advisers now focus on placing students into courses versus helping them out of courses. Enforced math placement has had a positive effect campus-wide, as other units are now reporting improvements in their core courses that heavily rely on PreCalc and Calc prerequisites. Attention is now being directed towards STEM initiatives to see what impact better course placement and outcomes are having in this area.

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