AC 2012-5540: USING ONLINE ASSESSMENT AND PRACTICE TO ACHIEVE BETTER RETENTION AND PLACEMENT IN PRECALCULUS AND CALCULUS

Alex Feldman, Boise State University

Alex Feldman is Associate Professor Emeritus of mathematics and computer science at Boise State University. He received a M.A. and a Ph.D. in mathematics and a M.S. in computer science from the University of Wisconsin, Madison. He is presently doing statistical studies on lower division courses in the Mathematics Department.

Dr. Doug Bullock, Boise State University

Doug Bullock is Chair and Associate Professor of mathematics at Boise State University. His research interests are in low dimensional topology, representation theory, quantum topology, and STEM education at the post-secondary level.

Dr. Janet Callahan, Boise State University

Janet Callahan is the Associate Dean for Academic Affairs at the College of Engineering at Boise State University and a professor in the Materials Science and Engineering Department. Callahan received her Ph.D. in materials science, her M.S. in metallurgy, and her B.S. in chemical engineering from the University of Connecticut. Her educational research interests include freshmen engineering programs, math success, K-12 STEM curriculum and accreditation, and retention and recruitment of STEM majors.

Using Online Assessment and Practice to Achieve Better Retention and Placement in Precalculus and Calculus

Abstract

In the fall of 2008 Boise State University began using an online assessment tool, ALEKS[1], as an initial assignment in Precalculus and Calculus courses. This paper reports on the effectiveness of the ALEKS assessment as a self-placement tool, used in conjunction with standard placement tests and prerequisite courses. The benchmark levels of 40% and 70% of knowledge space in the ALEKS course: *Preparation for Calculus* for Precalculus and Calculus courses were used. The paper looks at the effectiveness of the assessment with these benchmark levels as a first student assignment, both as a tool for student success, and as an instrument for making efficient use of the university's resources. Although there are no hard answers, and although much information is anecdotal, we introduce a statistic that is pertinent to these questions and show that it indicates partial effectiveness of the ALEKS assessment.

Introduction

Placing students into the proper mathematics course is challenging; across the United States colleges and universities employ a wide array of strategies. A study conducted at Merrimack College in Massachusetts by Rueda and Sokolowski[2] provides a literature review, citing works by Cederberg[3], Cohen, et al.[4], Krawczyk and Toubassi[5] and others. In looking over placement rubrics there does not appear to be consensus on any one particular strategy for placement. Many mathematics departments use a combination of ACT/SAT; others have developed home-grown tests that are used with reasonable success. Some use a combination of ACT/SAT, home-grown tests, and commercial placement exams (such as COMPASS). When available, prerequisite courses are also used.

For universities that enroll significant populations of students who have stopped out of school for a period of time, placement is particularly challenging. When there is a significant time lag between when a prerequisite course is taken and when then the next registration occurs, students may fail to retain adequate material from the prerequisite course. Placement exams can also be problematic. For example, COMPASS exams are designed to be taken without preparation, but often students do prepare for them, or take them several times, skewing the results. Also, the timing of a placement exam can result in improperly placed students. At Boise State it is not uncommon that newly enrolled freshmen took their ACT or SAT one time only, in their junior year of high school, because their scores at that time were sufficient for admission to the university. Most students in STEM majors (science, engineering, technology and mathematics) go on to take a subsequent math course, resulting in more knowledge than revealed by their ACT or SAT scores. Other students, not destined for STEM majors, may choose to not enroll in mathematics in their senior year of high school, resulting in lack of knowledge retention by the time they enter the university and eventually enroll in a required mathematics course.

When a student is placed in a class that is too easy it is a waste of time and resources, but the

situation will often right itself after one semester. If a student is placed in a class that is too difficult there are two serious deleterious effects:

1. The student may perform poorly, and fail the course or earn a grade damaging to the student's grade point average. There is a documented connection between first year GPA and graduation rate, so placement is crucial to student success.
2. The student will need to retake the course, occupying a seat that another student could have had. At Boise State University, Precalculus and first semester Calculus have been identified by the Enrollment Management Committee as bottleneck courses, i.e., courses that can be hard to enroll in and then to pass, but are needed as prerequisites for other courses in a major program. In an era where budgets grow slower than enrollments bottlenecks are bound to occur, but that does not excuse the systemic bottlenecks often encountered in these two courses. Any mitigation of bottlenecks would be worthwhile.

For the most part, placement at Boise State University is via a single event approach: a prerequisite course or a placement exam determines which course the student will be in, and that result is not revisited. Students who are new to the university are generally placed in courses based on their ACT or SAT results. It has become increasingly apparent that that approach is inadequate. Frequently, mathematics instructors will schedule an exam that cannot be graded before the deadline to drop a course, which at Boise State is the end of the 6th week of class. Unfortunately, by that time it is too late either for the student to switch to a lower level class that might be more appropriate, or for that student's vacated seat to be occupied by someone else.

It is worth exploring additional activities designed to refine or confirm placement. Such activities would take place early in the term so that students identified as unlikely to succeed would have a realistic option to move to different courses. An additional benefit would be that seats vacated by students exiting this early in the term would be available to other students waiting to gain access. Boise State University allows students to add or drop classes freely throughout the first week of instruction. This fact, together with the broad informal agreement that students should not miss more than a week of a semester-long math class, led us to focus on placement activities that can give a signal to the student no later than the end of the first week of class.

The two courses used in this student were Precalculus, which in the fall of 2011 had 10 standard sections with 376 students receiving a grade (including W), and first semester Calculus, which in the fall of 2011 had 10 standard sections with 378 students receiving a grade.

ALEKS

ALEKS (Assessment and LEarning in Knowledge Spaces) has been described in detail elsewhere[6,7], but briefly it is a battery of online adaptive tools that permit a student to work problems in a given course of study and get immediate feedback. It was designed to be used as a learning tool, and when used in this mode it includes a periodic assessment component that the student completes as part of their online learning.

ALEKS may also be used in an assessment mode only. This paper reports on results from this

mode only. The first use of ALEKS in an assessment mode (separate from the learning mode) to help assure proper student placement into a Precalculus or Calculus course occurred in fall of 2007 at the University of Illinois; the second university to use ALEKS in this mode was Boise State Universit, which deployed it in fall of 2008[6]. Boise State University adopted the same implementation strategy as the University of Illinois, which involved requiring a benchmark score during an unproctored ALEKS assessment. Achievement of the benchmark score by the end the add/drop cycle constituted 10% of the student's grade in the upcoming course. If this benchmark was not achieved, the underlying assumption was that students would self-select to a lower level course, rather than receive a zero for this rather heavily weighted first assignment. The benchmarks used initially by the University of Illinois and by Boise State were 40% and 70% for Precalculus and for Calculus, respectively. Boise State has retained these benchmark levels; however after a couple of years, the University of Illinois shifted theirs to the current levels of 50% and 70%[8]. Since these first implementations of ALEKS in assessment mode, a number of other universities have also implemented ALEKS in some manner as an assessment strategy; for example, Arizona State University[9], University of Arizona[10] and the University of Montana[11].

At Boise State University, ALEKS is used both as a confirmation of placement and as a learning tool, but the modules that were used in the courses described in this paper were mainly the assessment and reassessment modules for **Preparation for Calculus.** Different modules are used in different courses and settings. Further details of this implementation are given in Bullock, et al[6].

ALEKS at Boise State University

Since fall of 2008, the ALEKS Preparation for Calculus assessment (APFC) has been required for both Precalculus and Calculus I. The assessment has been required for summer courses as well as fall and spring. Data for summer classes has been omitted from this paper because there are not very many students in the summer classes, and because there are other inconsistencies between summer and regular terms that complicate comparisons. The chief source of these inconsistencies is the fact that summer term is 8 weeks long while fall and spring are 16 weeks long, which makes distinguishing between the first week versus the first two weeks difficult.

Students who attend orientation functions that precede the regular semesters are told about the assessment requirement and encouraged to take it as soon as possible. All enrolled students receive email reminders of the requirement in the weeks that lead up to the start of each semester. A few students assess well in advance, but most wait until the start of classes or the week before to attempt the assessment.

The APFC assessment is graded pass/fail, but weighted approximately equal to a midterm exam. Since the assessment is given online with no proctors present there is the potential for cheating. No studies have been done at Boise State to examine the extent of the possible cheating, but the spread of scores indicates if extensive cheating is going on, it is limited in its effectiveness. As Table 1 shows, only about half of the students generally attempt the assessment before the semester begins. It is worth noting that while early drops are about the same in Precalculus and Calculus I, the overall success rate for the assessment in Calculus is generally higher, while the

overall percentage of students taking and passing the assessment by the first day of class is generally higher in Precalculus. While this might be interpreted to mean the assessment had more impact in Precalculus, there are other possible explanations. There may be a lot more students in the Precalculus course who already have seen a lot of the material and for whom the assessment is relatively routine. It may also be easier to cheat on the Precalculus assessment, where a score of on 40% suffices, contrasted with the 70% required for Calculus I.

There have been some efforts by individual faculty to try to correlate final grades with scores on the APFC. While there may be useful pedagogical information to be found in that statistic, it is not clear that it is the most fruitful approach to discovering if the APFC is useful as a confirmation of placement. In order to investigate that question, data from fall and spring semesters from fall 2003 through fall 2011 were collected and analyzed. Since the APFC assessments began in fall 2008, this meant ten semesters without using APFC and seven semesters using AFPC. Among others, the following statistics were gathered:

- The percentage of students who dropped the course. This included early drops, defined as drops no later than the 10^{th} day, which thus cause the course to be removed the transcript; drops between the 10^{th} day and 6^{th} week, which are recorded as a W on the transcript; and complete withdrawals from the university, which if they are done after the 10^{th} day are recorded as a CW on the transcript.
- The percentage of students who must take the course again; that is all drops as described above, plus all D's and F's.
- The percentage of students who drop before the first day of class.
- The percentage of students who are early drops, as described in the first bullet.
- The ratio of early drops to all students who must take the course again, i.e., the ratio of the number of students who drop before the tenth day to the total drops plus D's plus F's. This last statistic has been dubbed the Early Drop Index or EDI in this paper.

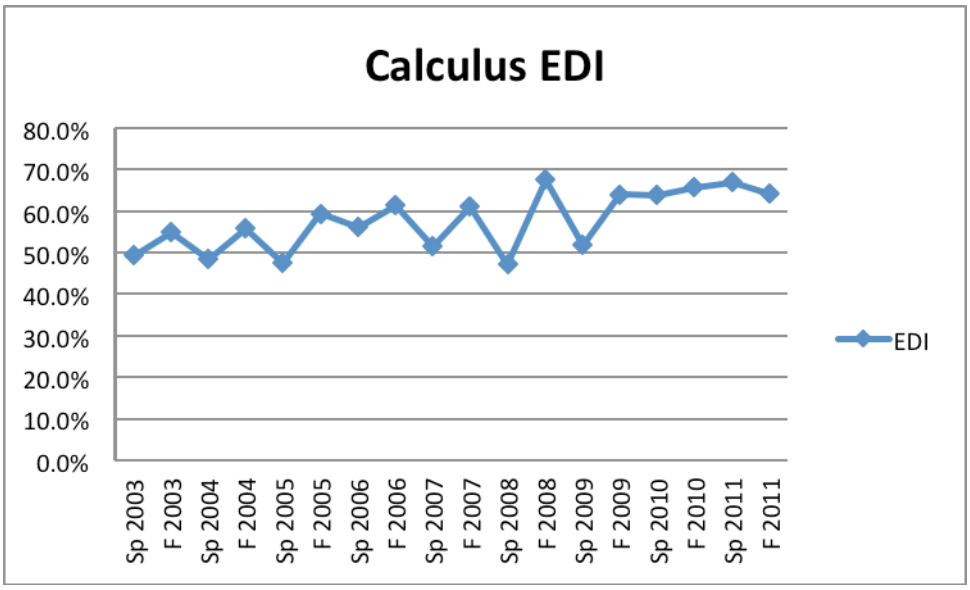
The EDI is proposed as an indicator of the effectiveness of any regime of placement. A high EDI indicates that most people dropping the class are doing so before they have a substantial investment in the course and suggests that the placement regime is good at allowing students to either select an appropriate course or make an early adjustment to a more suitable course. A low EDI indicates that many people are failing to master the material even after a significant investment in the course. Our hope is that adding a confirming assessment to the traditional one shot placement mechanism will achieve a higher EDI.

The EDI is an imperfect measure of placement effectiveness, as there are many reasons why a student might perform poorly in a class, even if placed correctly. The instructor in the class may be ineffective; the student may experience a significant or traumatic event outside of the class and have to readjust priorities; the student may re-evaluate his or her goals mid-semester and lose interest in the course; or any number of other things. However, given a single university environment with a stable cadre of instructors, many of these issues will balance out over time. Since placement is the only aspect of the course that has had a major overhaul during the study period, it is reasonable to expect that any change in the EDI over this period is at least partly attributable to the addition of a confirming assessment after the initial placement.

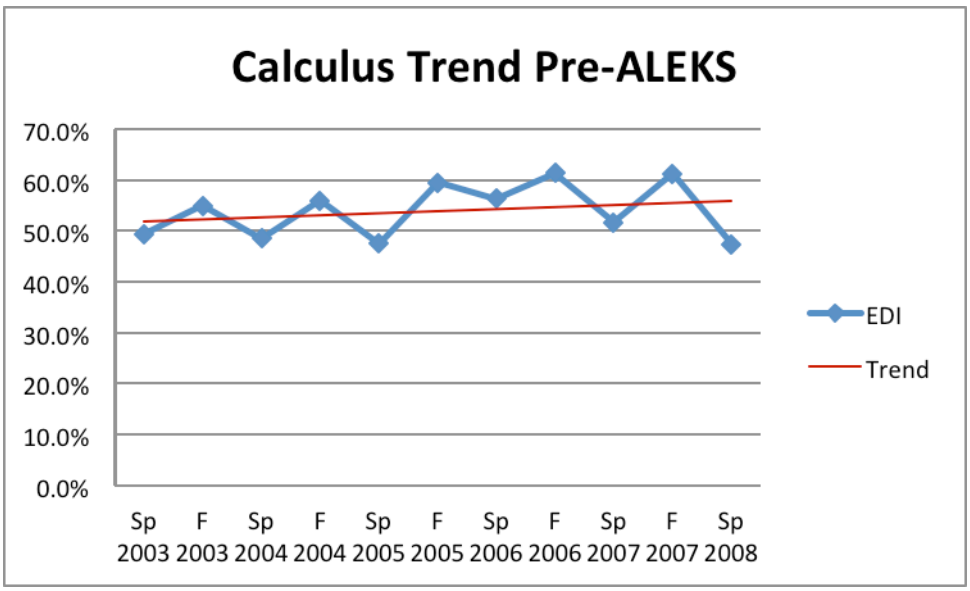
Ultimately, students who withdraw from a course do so of their own volition. Students have access to academic advisers and sometimes discuss the decision to drop with their instructor. We have no data on how much of this discussion goes on and how much it influences a student's decision to withdraw or continue with the course.

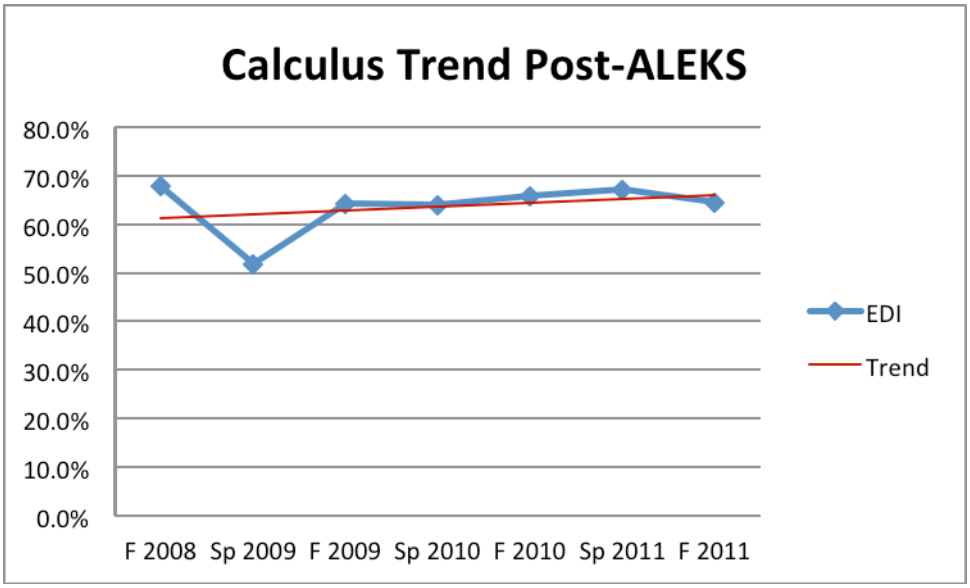
Results

All results described here are extracted from the data attached in Tables 1 and 2 (appendixes). Our central question is what, if any, changes to EDI occurred when ALEKS was implemented in fall 2008. Here is EDI for Calculus graphed against time, from fall 2003 to fall 2011.

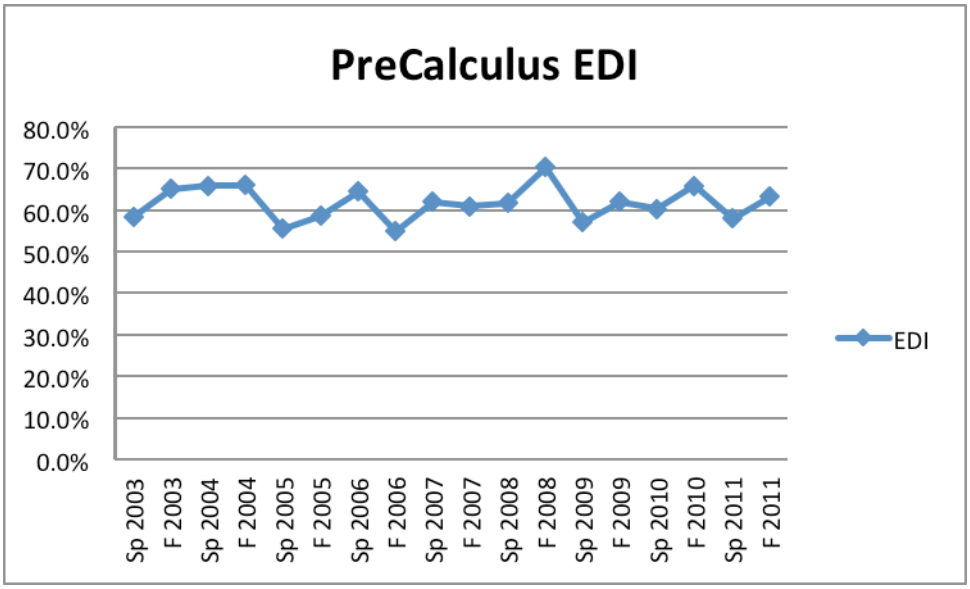


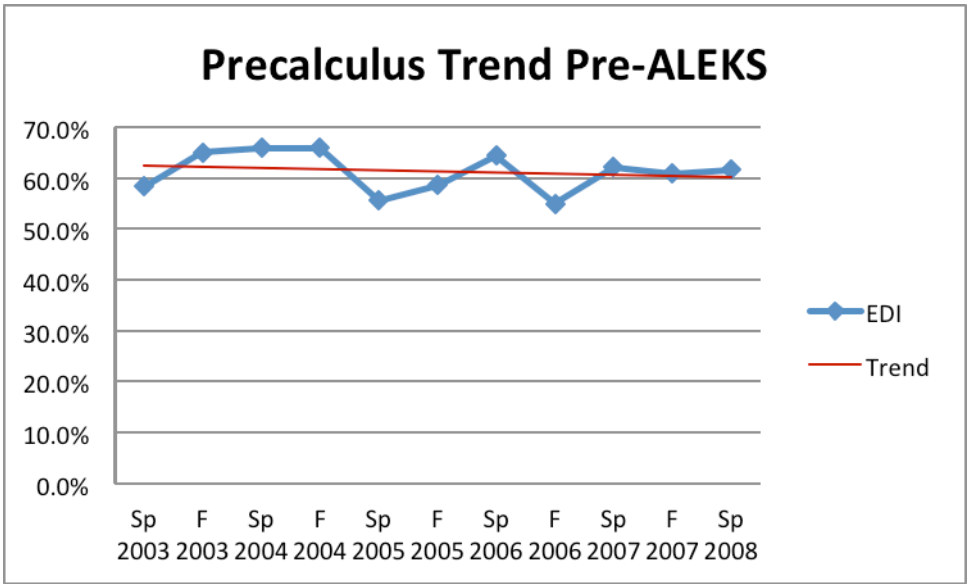
There is a notable jump in EDI in the fall 2008 semester, then a return to relatively low EDI one term later, followed by a much less volatile sequence of semesters with fairly high EDI. The change from pre-ALEKS to post-ALEKS is more evident in the next two graphs: one shows the linear trend in EDI up to spring 2008, and the other shows trend after 2008.

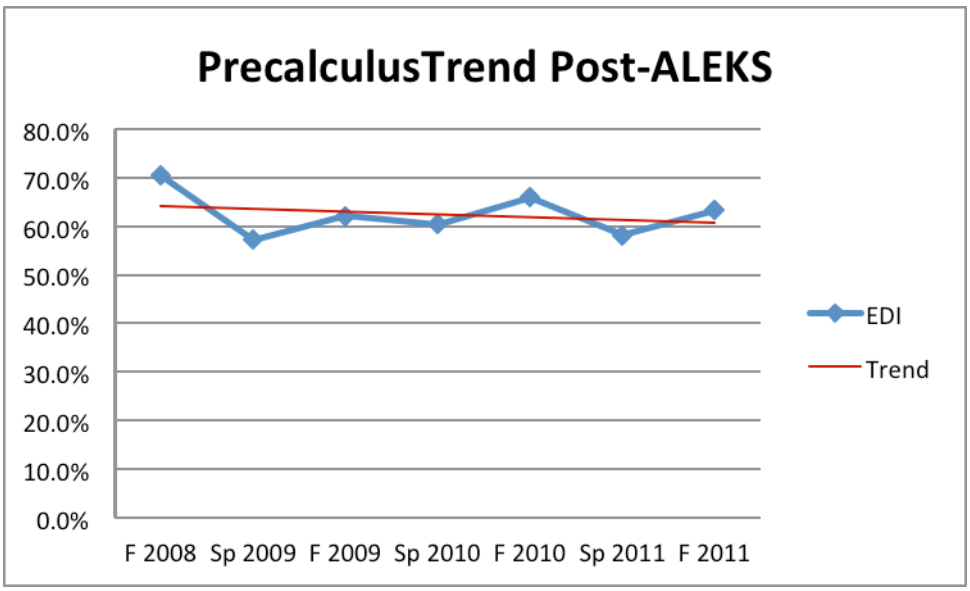




There is a clear difference in behavior before and after ALEKS. Through spring 2008 the EDI trend was nearly flat at about 54%. After ALEKS the trend is again nearly flat, but jumps to about 63.5%. The corresponding graphs for Precalculus show much less impact. There is a similar upward jump in EDI in the implementation semester (fall 2008), but general behavior as shown in the before and after trends does not seem much affected. The pre-ALEKS trend averaged an EDI of 61.3%, while the post-ALEKS trend averaged 62.5%.


PreCalculus EDI
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Sp 2003
F 2003
Sp 2004
F 2004
Sp 2005
F 2005
Sp 2006
F 2006
Sp 2007
F 2007
Sp 2008
F 2008
Sp 2009
F 2009
Sp 2010
F 2010
Sp 2011
F 2011
EDI


Precalculus Trend Pre-ALEKS
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Sp 2003
F 2003
Sp 2004
F 2004
Sp 2005
F 2005
Sp 2006
F 2006
Sp 2007
F 2007
Sp 2008
EDI
Trend



Analysis

The data provided here show almost no difference in EDI at the break point in fall 2008 for Precalculus, but there is a reasonable difference for Calculus. Students and instructors seemed to be on board with the idea of the assessment, since by the deadline at the end of the first week, at least 98% of the students had completed a satisfactory assessment. This indicates relatively modest pushback – few instructors were letting students off without taking the assessment, and relatively few students were trying to get away without taking it. It is reasonable to assume that some of the students who did not take the assessment by the deadline had already decided to drop the class, but had not formally done so yet. Anecdotal evidence suggests that there are always some students enrolled in these classes who have no intention of finishing but put off dropping the class, or never bother to do it at all.

The assessment appears to be providing some value for Calculus and has been retained for spring 2012. After using the assessment from fall 2008 through fall 2011, it was judged that the effectiveness for Precalculus was not worth the costs and inconvenience.

Further Study

Data is presently being gathered for a longitudinal study for these same students to see how they performed in Calculus 2 and possibly some non-math courses that use Calculus. Pass rates and grades are also being examined to see what kind of predictive effect a score on the assessment might have.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant No. 0856815. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

References

1. http://www.aleks.com/

2. Rueda, N.G. & Sokolowski, C. (2004). Mathematics Placement Test: Helping Students Succeed. The Mathematics Educator, 14 (2) (pp. 27-33).

3. Cederberg, J. N. (1999). Administering a placement test: St. Olaf College. In B. Gold, S. Keith, & W. Marion (Eds.), Assessment practices in undergraduate mathematics (pp. 178−180). Washington, DC: Mathematics Association of America.

4. Cohen, E., Friedlander, J., Kelemen-Lohnas, E., & Elmore, R. (1989). Approaches to predicting student success: Findings and recommendations from a study of California Community Colleges. Santa Barbara, CA: Chancellor's Office of the California Community Colleges. (ERIC Document Reproduction Service No. ED 310808)

5. Krawczyk, D., & Toubassi, E. (1999). A mathematics placement and advising program. In B. Gold, S. Keith, & W. Marion (Eds.), Assessment practices in undergraduate mathematics (pp. 181−183). Washington, DC: Mathematics Association ofAmerica.

6. Bullock, D, Callahan, J, Ban, Y, Ahlgren, A, & Schrader, C. (2009). "The Implementation of an Online Mathematics Placement Exam and its Effects on Student Success in Precalculus and Calculus," American Society for Engineering Education Annual Conference & Expo, Austin, TX AC 2009-1783

7. http://www.aleks.com/about_aleks/publications_kst Downloaded 1/11/12.

8. http://www.math.illinois.edu/ALEKS/ Downloaded 1/11/12.

9. https://students.asu.edu/math Downloaded 1/11/12

10. http://math.arizona.edu/academics/placement/mpt/aleksfaq.html Downloaded 1/11/12

11. http://www.umt.edu/mathplacement/ Downloaded 1/11/12

Appendix.

The following two tables contain the grade and drop data for the study period for Precalculus and Calculus. Column O contains the EDI or Early Drop Index, described above. "Pre drops" are drops that occur before the first day of class; "10 day drops" are drops that occur during the first 10 days of class. "10 days" is a term of art at Boise State – it usually means 2 weeks. Fall 2008 is the first time that assessments were used, so there is shading change starting in that row. All of these data reflect only genuine drops – formally, when a student switches sections it is recorded as a drop followed by an add. Those drops are not included in the data.

Precalculus															
Term	**A**	**B**	**C**	**D**	**F**	**Pre drop**	**10 day drop**	**W, CW, Late**	**Total**	**Drop %**	**Drop+F+D %**	**Pre drop %**	**Pre+10 Dr %**	**EDI**	**Pass Rate**
Sp 2003	50	80	86	48	99	166	78	26	633	42.7%	65.9%	26.2%	38.5%	58.5%	55.5%
F 2003	55	77	91	53	93	232	94	29	724	49.0%	69.2%	32.0%	45.0%	65.1%	56.0%
Sp 2004	26	69	73	41	41	136	61	20	467	46.5%	64.0%	29.1%	42.2%	65.9%	62.2%
F 2004	35	80	93	37	72	185	76	25	603	47.4%	65.5%	30.7%	43.3%	66.1%	60.8%
Sp 2005	23	36	63	21	85	110	53	24	415	45.1%	70.6%	26.5%	39.3%	55.6%	48.4%
F 2005	36	49	63	35	130	180	87	23	603	48.1%	75.5%	29.9%	44.3%	58.7%	44.0%
Sp 2006	33	47	54	27	61	141	58	22	443	49.9%	69.8%	31.8%	44.9%	64.4%	54.9%
F 2006	42	79	70	23	83	142	62	61	562	47.2%	66.0%	25.3%	36.3%	55.0%	53.4%
Sp 2007	27	62	37	25	53	123	59	33	419	51.3%	69.9%	29.4%	43.4%	62.1%	53.2%
F 2007	69	113	87	32	84	179	65	40	669	42.5%	59.8%	26.8%	36.5%	61.0%	63.3%
Sp 2008	34	52	52	26	72	127	67	22	452	47.8%	69.5%	28.1%	42.9%	61.8%	53.5%
F 2008	72	89	77	36	77	203	98	13	665	47.2%	64.2%	30.5%	45.3%	70.5%	65.4%
Sp 2009	23	47	58	20	105	132	72	28	485	47.8%	73.6%	27.2%	42.1%	57.1%	45.6%
F 2009	35	70	96	44	112	246	68	36	707	49.5%	71.6%	34.8%	44.4%	62.1%	51.1%
Sp 2010	20	66	52	33	77	128	56	11	443	44.0%	68.8%	28.9%	41.5%	60.3%	53.3%
F 2010	51	58	76	42	106	212	92	9	646	48.5%	71.4%	32.8%	47.1%	65.9%	54.1%
Sp 2011	31	53	60	24	87	119	64	21	459	44.4%	68.6%	25.9%	39.9%	58.1%	52.2%
F 2011	49	72	95	35	94	216	63	33	657	47.5%	67.1%	32.9%	42.5%	63.3%	57.1%
Totals	**711**	**1199**	**1283**	**602**	**1531**	**2977**	**1273**	**476**	**10052**					**61.7%**	**54.7%**

Calculus 1															
Term	**A**	**B**	**C**	**D**	**F**	**Pre drop**	**10 day drop**	**W, CW, Late**	**Total**	**Drop %**	**Drop+F+D %**	**Pre drop %**	**Pre+10 Dr %**	**EDI**	**Pass Rate**
Sp 2003	26	39	51	31	45	63	24	13	292	34.2%	60.3%	21.6%	29.8%	49.4%	56.6%
F 2003	44	79	65	35	90	140	41	24	518	39.6%	63.7%	27.0%	34.9%	54.8%	55.8%
Sp 2004	42	36	47	13	88	85	26	17	354	36.2%	64.7%	24.0%	31.4%	48.5%	51.4%
F 2004	37	48	41	30	73	149	31	39	448	48.9%	71.9%	33.3%	40.2%	55.9%	47.0%
Sp 2005	24	37	39	27	71	87	25	26	336	41.1%	70.2%	25.9%	33.3%	47.5%	44.6%
F 2005	35	47	64	24	72	151	41	35	469	48.4%	68.9%	32.2%	40.9%	59.4%	52.7%
Sp 2006	28	31	47	17	54	98	23	23	321	44.9%	67.0%	30.5%	37.7%	56.3%	53.0%
F 2006	37	57	58	18	64	131	36	23	424	44.8%	64.2%	30.9%	39.4%	61.4%	59.1%
Sp 2007	25	62	56	19	59	80	18	14	333	33.6%	57.1%	24.0%	29.4%	51.6%	60.9%
F 2007	75	79	67	32	62	155	44	32	546	42.3%	59.5%	28.4%	36.4%	61.2%	63.7%
Sp 2008	58	46	45	36	71	76	39	21	392	34.7%	62.0%	19.4%	29.3%	47.3%	53.8%
F 2008	69	91	69	25	67	168	61	17	567	43.4%	59.6%	29.6%	40.4%	67.8%	67.8%
Sp 2009	40	56	72	28	64	81	34	15	390	33.3%	56.9%	20.8%	29.5%	51.8%	61.1%
F 2009	77	92	65	33	76	186	51	24	604	43.2%	61.3%	30.8%	39.2%	64.1%	63.8%
Sp 2010	42	72	84	33	72	148	59	12	522	42.0%	62.1%	28.4%	39.7%	63.9%	62.9%
F 2010	80	118	84	31	71	181	62	24	651	41.0%	56.7%	27.8%	37.3%	65.9%	69.1%
Sp 2011	36	69	97	22	51	150	48	24	497	44.7%	59.4%	30.2%	39.8%	67.1%	67.6%
F 2011	51	76	104	47	79	211	56	22	646	44.7%	64.2%	32.7%	41.3%	64.3%	60.9%
Totals	**826**	**1135**	**1155**	**501**	**1229**	**2340**	**719**	**405**	**8310**					**57.7%**	**58.4%**