Essex County College
PBI Grant Final Report
Activity 1: Emporium Teaching Model in Developmental Mathematics

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Introduction

A $50,000 Predominantly Black Institution (PBI) grant was awarded to support the development of an adaptive/self-regulated learning model in developmental math courses for 2014-2015. This is a continuation of grants received for the past four years. The specific courses that were supported were Introductory Algebra (AFM 083) and Elementary Algebra (MTH 092).

Program Description

The new learning model is composed of two components: self-regulated learning and adaptive math technology.

Self-Reguluated Learning

The College worked with a consultant from the Center for Advanced Studies in Education at the SUNY Graduate Center to develop the self-regulated learning curriculum. Here is a brief synopsis of the lessons:

1. Introduction to Active Learning - This section presents the idea that being an effective learner depends on much more than IQ, and presents statistics on low graduation rates and low pass rates in math as attention-getting devices to create interest in understanding what students can do to increase their likelihood of success. Students read a definition of active learning, assess themselves on an active learning scale, and discuss whether they are inherently "bad at math" or whether that attitude is just an excuse for not taking an active role in their own learning. This is a first step toward challenging the "fixed mindset" that is common among math students.
2. Learning Science - This section introduces students to the idea that intelligence is not fixed but can be developed through concentration, practice, and reflection, in other words a "growth mindset" vs. a "fixed mindset." We present the fact that knowledge is encoded in the brain as connections between neurons, and the growth of new connections depends on concentration and practice, much as the growth of new muscles depends on repetitive exercise. Dweck1 has shown that students with a growth mindset make greater learning gains than students with a fixed mindset and has presented evidence that students with a growth mindset are able to remediate their mistakes because they experience failure as an opportunity to learn, while those with a fixed mindset do not.
3. Learning Communities - Uri Treisman's seminal study in the late 1970's demonstrated that a pattern of social and intellectual isolation among African-American students was a key factor contributing to high failure rates in math. The implementation of mandatory study groups, where students work through problems collaboratively with minimal guidance from an instructor, produced significant gains in student performance. In this unit we introduce students to Uri Treisman's work, and students are required to form study groups, exchange contact information, and work together on difficult math problems. Treisman's model has been replicated at hundreds of universities in different forms and there are multiple studies showing effectiveness in a variety of implementations.
4. Grit - Duckworth defines grit as "the tendency to sustain interest in and effort toward very long-term goals." In a 2005 article2, Duckworth and Seligman showed that 8th grade students' self-discipline is a better predictor of their final grade than IQ, attendance, hours spent doing homework, and hours spent watching TV. Dozens of subsequent studies confirmed the importance of grit for success in long-term efforts such as school, marriage, career, and the military. Students are introduced to Duckworth's research and a self-assessment of "grittiness."
5. Goals and Strategies - Goals that are SMART (Specific, Measurable, Achievable, Relevant, Time-framed) are used to define success and make it visible, concrete. Strategies are specific behaviors or actions that help you attain the goal, such as turning off your phone when you study or creating a written schedule of study times. Taken together, goals and strategies represent a plan, which is a key component of Self-Regulated Learning (SRL). In this unit, students define one-week goals and strategies and review them with their peers. Students will revisit the goals and strategies in a week to assess their performance.
6. Self-Monitoring - This unit emphasized day-to-day monitoring of performance to ensure that strategies are being followed and progress is being made toward the goals. Students have check-lists to mark their prog-

ress during the week. Self-monitoring is essential to Self-Regulated Learning because it provides a record of practice and performance that will be used to support the evaluation stage of the self-regulated learning cycle.

7. Feedback a.k.a. Formative Assessment - Feedback is essential to learning, but as Dweck has shown, students with a fixed mindset often misinterpret corrective feedback as a negative judgment on their intelligence instead of as an opportunity to learn from their mistakes. In this unit we confront students' emotional responses to negative feedback, revisit "fixed" and "growth" mindsets, and then move beyond the visceral response to focus on the indispensable role of feedback in the learning process. The productive use of feedback is central to self-regulated learning and logically follows the creation of measurable goals.
8. Time Management - The development of time management strategies and recognition of problems such as procrastination are the focus of this unit. Students have seen daily planners and Google calendar in the College Success course, but that doesn't mean they have employed those tools. In this unit, students create written schedules that will be tracked weekly to see how well they follow their own schedule. Tracking time-on-task is made easier for the instructor by the adaptive learning technology, which generates weekly reports on each student.
9. Self-Assessment - The ability to accurately predict future performance on an academic task such as an exam is one of the most advanced skills in self-regulated learning. Students almost universally overestimate future performance and thus under-prepare. In this unit we introduce a process for predicting performance before beginning a task, subsequently evaluating the accuracy of the prediction, and then explaining the discrepancy between predicted and actual performance. Repetition of this process over several weeks produces steady improvement in students' predictive abilities.
10. Recognizing Effective Strategies - This unit emphasizes action: making change based on feedback. When a goal has not been met, the strategies that were designed to attain the goal have to be examined for effectiveness. If studying before your work shift hasn't worked, then other study times have to be found. If asking your siblings not to interrupt you while you study at home has not worked, then another approach has to be taken. If putting your phone on vibrate doesn't prevent you from talking and texting when you should be studying, then something else has to be done with your phone. Self-regulated learning in its simplest form is a cycle of planning, practicing, and evaluating, and the evaluation phase requires more than just receiving feedback, it requires using feedback to improve performance.
11. Stereotype Threat - This unit explores recent research on stereotypes and how they interfere with academic performance3,4. When a student belongs to a group with a negative stereotype and is given a difficult task that is linked to the stereotype, the student performs below her ability whether she believes the stereotype or not. Women and math tests, blacks and IQ tests, whites and tests of athletic skill have all been shown to perform below their abilities when the task is linked to a negative stereotype and to perform in accordance with their abilities when an identical task is framed in a way that is not linked to the stereotype. In this unit we explore stereotypes of minorities, women, adult learners, people who are overweight, people with physical disabilities, etc. and how those stereotypes can undermine their academic performance even when they don't believe the stereotypes.
12. Planning for Learning - This unit integrates previous work on the cycle of planning, practicing, and self-evaluation and presents them as components of a holistic approach to the planning cycle self-regulated learning.13. Stress Management - This unit examines the role of stress, why it is good and bad, and provides stress reduction exercises.

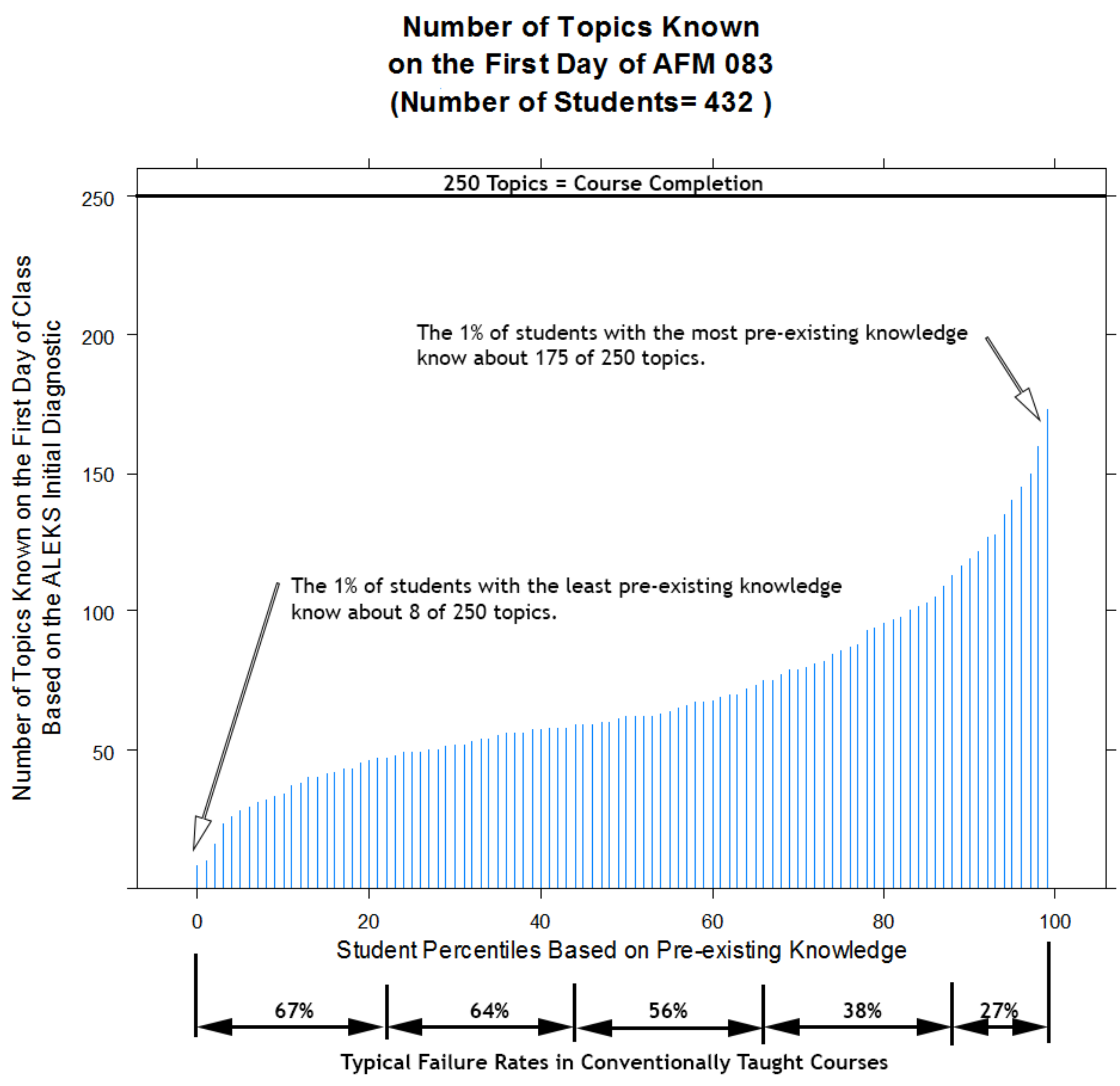
The self-regulated learning curriculum reflects the latest research from a number of research centers and was implemented for the first time in Fall 2013 with 450 developmental math students and has been offered every semester since then.

Adaptive Math Technology

One of the biggest challenges with teaching developmental math is the wide range of abilities of the students. Introductory Algebra (AFM 083) enrolls students with skill levels as low as fourth grade or as high as eleventh grade. Some are still learning their multiplication tables, while others are ready to graph equations in two variables. It is almost impossible to create a lesson plan that doesn't leave many students bored and many others lost.

The advantage of adaptive technology is that it can analyze the work each student has done correctly, the mistakes each one has made, and based on that history predict what each student is ready to learn and serve that to them so they are never bored and never lost. So, a key advantage of technology is that it individualizes learning.

The adaptive math technology divides each course into 200 to 250 small topics, and on the first day of class students take a 45-minute diagnostic exam to see how many of those topics they already know. The results of the diagnostic exam for Introductory Algebra for Fall 2013 are shown below. It is immediately obvious that the least-prepared students know less than 5% of the course material while the best-prepared students know more

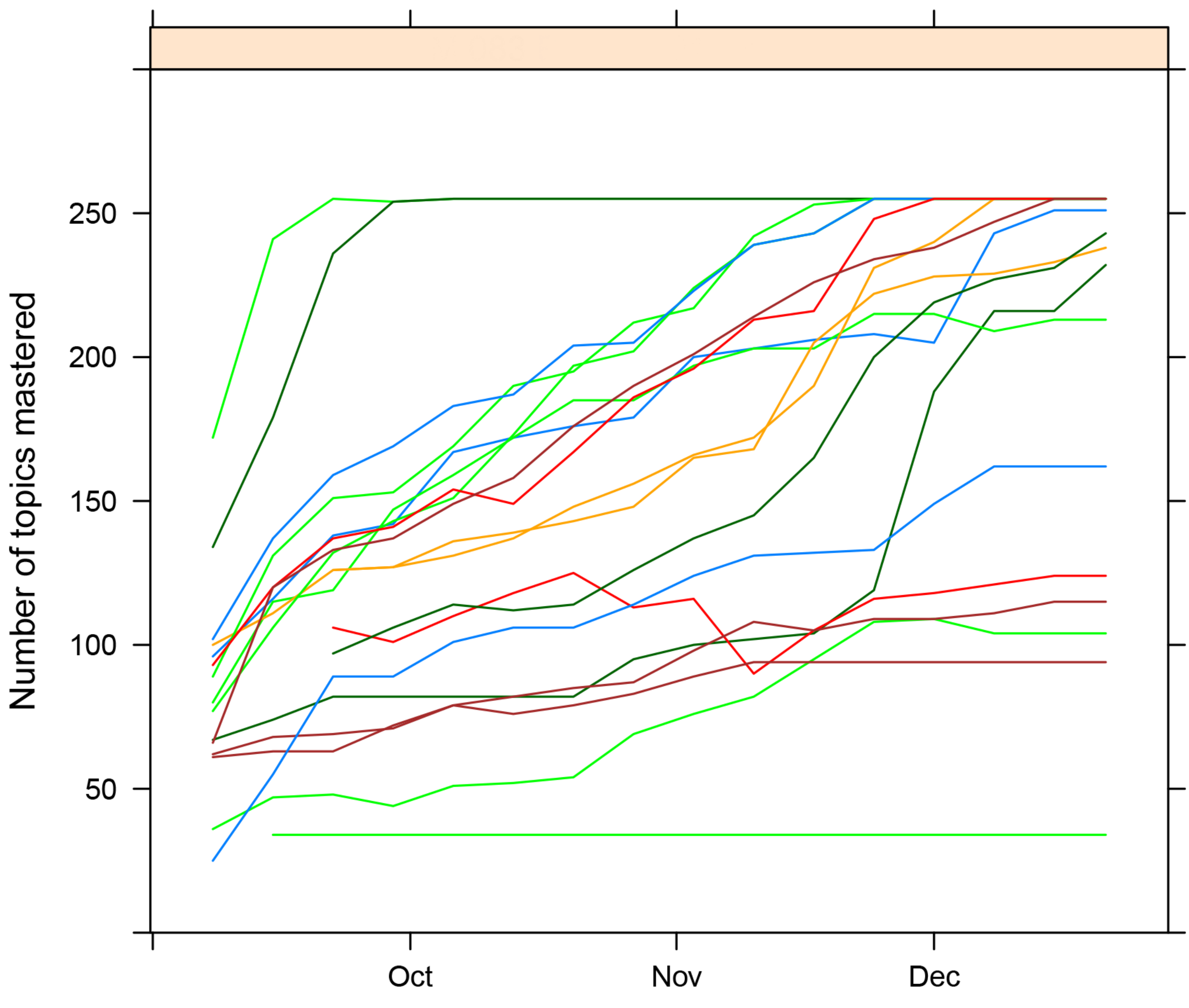


than 70% of the course material, again reinforcing the fact that there is a wide range of pre-existing knowledge that requires an individualized approach.

Once the diagnostic is complete, students begin their work. Students attend class three times a week for 80 minutes just like a conventional class, but they spend class time actively solving problems and mastering new topics instead of passively listening. If they need help they can access it within the software or they can raise their hand and ask an instructor or assistant instructor. The figure below shows an example of student progress in one class:

the horizontal axis represents the fall semester from September to December, and the vertical axis represents the topics in the course. Each line in the graph represents an individual student. (There are 19 lines representing 19 students.) In the upper left of the graph are two lines (two students) who started in September with pre-existing knowledge of about 135 and 175 topics. Both students mastered all the remaining topics in the course before the end of September, took the pencil-and-paper department-standard final exam, passed it, and immediately moved on to the next course in the sequence. They did not need to spend fifteen weeks in this course. About 5% of our students were able to finish two courses in a single semester. A second group of students started with pre-existing knowledge of about 75 to 100 topics. These students mastered 10 to 15 topics a week and finished the course in late November or early December. A third group started with pre-existing knowledge of less than 75 topics, and they mastered about 10 topics a week and didn't finish the course. But they didn't get a D or an F, they got an M for "Making Progress" and when the spring semester began they continued where they left off. We have one student at the bottom of the graph who made no progress because she never came to class; she will get a grade of N which means "Not Attending," and when that student registers for math again she will have to meet with an

Number of topics mastered during the Fall semester
The complete course is 255 topics
Each line represents one student



advisor to see how we can avoid repeating that behavior. Once again, the way we implement technology gives us insight into learning as a continuous process. It is also worth noting that on any particular day, each student is at a different point and is being served with material that is exactly at the level where they are ready to learn.

Methods

About 20% of developmental math courses were taught using adaptive/self-regulated learning (treatment courses), and the remainder were taught using conventional methods (control courses). Although some students begin their first math course in the fall and others begin in the spring, the majority of students begin in the fall, and in order to simplify the analysis we limited our study to students who took their first math class in the fall. Some students start with 80-level math, but others place out of 80-level math and start with 90-level math. The majority of students start with 80-level math, and these are the students who have the most trouble passing college-level math, so to simplify the analysis we limited this study to students who started in 80-level math.

We divided the students into three groups: (1) students who took their first math class in the Department of Math and Physiccs, which offers conventional lecture-based courses and is the control condition, (2) students who took their first math class in the Center for Academic Foundations prior to Fall 2013, which provided a standard lecture-based calendar-driven course supplemented by tutorials and ALEKS adaptive software and is the first treatment condition, and (3) students who took their first math class in the Center for Academic Foundations in Fall 2013 or later, which provided a mastery-based emporium-style course with ALEKS adaptive software as the primary means of math instruction accompanied by twice-weekly lessons in self-regulated learning and is the second treatment condition.

All students take their first math class in either the Department of Math and Physics (DMP) or the Center for Academic Foundations (CAF). Subsequent math courses may switch from one to the other. We find that about 98% of students who start in DMP and go on to take a second course will take their second course in DMP, while only about 22% of students who start in CAF and go on to take a second course will take their second course in CAF. The low rate of continuation in CAF is probably due to the fact that DMP offers far more sections of 90-level math than CAF and students primarily choose their courses based on what fits in their schedule. Once students complete 90-level math they take 100-level math, and all 100-level math courses are taught in the Department of Math and Physics using conventional lecture-style classes. So, students can switch between CAF and DMP, but we hypothesize that the first math class that they take can make a difference in whether they eventually pass college-level math. So, we examine students based on their first math class, and we understand that their subsequent math classes may be in traditional or non-traditional formats.

We tracked students who started their first math class from Fall 2011 to Fall 2014 and determined which students passed college-level math in two years or less. We analyzed the probability of passing based on whether the student's first math course was in CAF or DMP and the student's Accuplacer score in computational math (CM), a.k.a. arithmetic.

Results

The ultimate goal of the adaptive/self-regulated learning model for developmental math is to increase the percentage of students who complete college-level math within two years. The time-span of this report extends for two years for students who started in Fall 2013 or earlier but only five terms for students who started in Fall 2014. (There are four terms in a calendar year: Fall, Spring, Summer I & Summer II.) The table below compares students in treatment and control sections and shows the percentage of students who passed college-level math in two years or less based on their score on the arithmetic Accuplacer test (CM). A visual examination of the data shows that Accuplacer score is very important, and it also suggests that students in treatment sections have a higher probability of passing college-level math in two years compared to students in control sections. It is also apparent that treatment sections have larger proportions of students with very low Accuplacer scores.

Percentage of students who started in 80-level math and passed college-level math in 8 terms (2 years) or less								
CM Quintile	Fall 2011 Cohort		Fall 2012 Cohort		Fall 2013 Cohort		Fall 2014 Cohort	
	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control
5	37% (n=49)	28% (n=336)	31% (n=62)	30% (n=259)	22% (n=46)	29% (n=257)	15% (n=20)	22% (n=264)
4	16% (n=61)	20% (n=309)	16% (n=80)	17% (n=327)	28% (n=60)	24% (n=338)	17% (n=24)	10% (n=311)
3	18% (n=33)	14% (n=234)	25% (n=53)	16% (n=188)	10% (n=58)	14% (n=215)	24% (n=17)	10% (n=201)
2	12% (n=178)	10% (n=297)	6% (n=87)	11% (n=277)	10% (n=111)	12% (n=336)	9% (n=45)	7% (n=376)
1	8% (n=203)	7% (n=250)	10% (n=177)	9% (n=249)	8% (n=165)	12% (n=244)	5% (n=56)	7% (n=286)
All	14% (n=524) avg(CM)=31.8	16% (n=1426) avg(CM)=41.1	15% (n=459) avg(CM)=34.6	17% (n=1300) avg(CM)=40.0	13% (n=440) avg(CM)=32.8	18% (n=1390) avg(CM)=39.4	11% (n=162) avg(CM)=33.6	11% (n=1438) avg(CM)=38.7

We conducted a logistic regression with a model that says the probability of passing college-level math in two years depends on the Accuplacer quintile and whether your first math class is adaptive or not:

Pr(pass) = f(quintile, adaptivity)

The "adaptivity" variable has three levels: (1) conventional courses with no adaptivity, a.k.a. the control, (2) adaptive courses prior to Fall 2013 where adaptivity was not emphasized, and (3) adaptive courses from Fall 2013 onward where adaptivity was central to the course. The best-fit model of the logistic regression model provides estimates as shown in the table below.

Estimated probability of passing college-level math in two years or less based on CM quintile and type of course. Probabilities were generated by the statistical model.			
CM Quintile	Conrol (Fall 2011-2013) (n=1726)	Treatment (Fall 2011-2012) (n=983)	Treatment (Fall 2013) (n=440)
5	24%	30%	28%
4	16%	21%	20%
3	11%	15%	14%
2	8%	11%	10%
1	7%	9%	8%

The table shows that students in the treatment sections have a 2% to 5% higher probability of passing college-level math in two years or less compared to the control sections. The improvement is statistically significant at the 0.0001 level for the treatment group from Fall 2011-2012. The improvement is not statistically significant, but this is probably due to the comparatively small n.

If the model's estimates are correct, then switching all sections to the treatment condition would increase the number of students passing college-level math in two years or less from about 530 to about 640 per year (assuming 2,000 students take 80-level math each semester with 400 in each quintile), which is a 20% increase.

Discussion

The Center for Academic Foundations (CAF) has always offered an enhanced learning experience in developmental math for students with the lowest placement scores. Prior to Fall 2013, the classroom offered a traditional lecture but with a supplemental instructor in the classroom, and a dedicated tutorial session with the supplemental instructor and ALEKS software, but usage data show that students spent averaged than an hour per week on ALEKS. Starting in Fall 2013 the classroom was changed into an emporium-style mastery-based course with

ALEKS as the primary vehicle for math instruction, and a dedicated tutorial session focusing on self-regulated learning. Passing rates in CAF before Fall 2013 were relatively high (60% or more), but passing rates from Fall 2013 onward are very low (about 30%), but the eventual pass rates in college-level math are comparable. So, one important observation is that when the course format changes significantly, in this case from an enhanced conventional format to a mastery-based emporium-style format, passing rates can represent different levels of learning. Waiting two years until many students are in college-level math provides a much more stable measure of learning.

It is worth noting that only the first cohort of students in the mastery-based courses are included in this analysis because two years have not elapsed since the start of the second cohort in Fall 2014. That first cohort, like many first cohorts, was subject to a lot of "learning" as the instructors adapted to the new format and learned to use ALEKS in ways that supported the new format. We expect the second and subsequent cohorts will perform bet- ter than the first cohort because the faculty have developed their skills at teaching in the new format.

Despite the fact that we only had the first cohort in the new format, the new format seems to be almost as ef- fective as the previous format, and we believe subsequent cohorts will have success rates that surpass those of students in the previous format. Both new and old formats are effective: the probability of passing college-level math in two years or less is 2 to 5 percentage points higher than the traditional format, which results in approx- imately 20% more students passing college-level math in two years or less. Thus, the experiment with innovative teaching formats has produced positive results.