MATH TRANSFORMATION PLANS

The Arizona Board of Regents has set an ASU goal to lead "Math Transformation". The instructions include:

- ASU will lead the design and launch of "Math Transformation" to eliminate math as a "rate limiter" for student success in both STEM and all other areas of study.
- Achievement of this goal will include the design and launch of a learning approach using adaptive learning platforms capable of changing ASU course success rates to more than 80% mastery from around 50%.
- At least 3 large scale deployed courses must be transformed.

1. EVOLUTION OF ASU'S ADAPTIVE LEARNING PLATFORMS

Phase 1

In terms of innovative approaches to math instruction, ASU is well ahead of other universities. At a recent "Pathways" meeting hosted by the APLU, ASU had already advanced beyond the plans being proposed at Pathways, sometimes as long as 8 years ago. In terms of math pedagogy, ASU has been the leader in adaptive learning technology from the beginning, 2011. At a different APLU meeting of institutions that each had been awarded a $550,000 grant for purposes of adopting adaptive learning courseware, including ASU, no one was at our stage. Moreover, ASU is well positioned to maintain our international leadership with a new broad based project involving calculus and the expansion of the innovative GFA math courses, both to be discussed in the last section of this report. ASU is well positioned to implement with success the type of courseware imagined in ABOR's directive for math performance and leadership in transforming math education.

Starting in 2011, ASU was the first university to introduce courseware that was truly adaptive, spurred by a critical need to improve student proficiency in foundational math skills. Too many students were failing to advance towards a degree because they were unable to pass a college level math course; and various attempts to solve the problem ended in failure. As we usually use the term in math, adaptive learning means courseware that can progress students through learning objectives on a personalized path by measuring each student's proficiency on each learning objective. If the student attains the required proficiency (normally 90%) on a learning objective they progress to the next lesson. If not, they review. If they again fail to get the required proficiency score, they can be remediated lesson by lesson. Three courses were launched in 2011: MAT110 (foundational math for non-credit); MAT117 (College Algebra); and MAT142 (College Mathematics, which has less algebraic content than MAT117). Developmental Math and College Algebra long have been recognized as the problem courses with which universities struggle nationwide. A great deal of effort has been spent on trying to improve student performance in these two courses across almost all of higher education.

Grade performance is displayed below. Before discussing the results, it is important to understand the nature of the data. The "success rate" that is reported is the percent of students initially enrolled in the course receiving an A, B or C grade. To keep comparisons consistent over time periods, only grades for on-campus sections are reported as the overwhelmingly dominant option available to students when the transition to adaptive learning took place. Finally, before reviewing the data, it is important to recognize that there were four notable changes that occurred in these three courses that could affect reported grades. First, class size doubled to 100 students on average because the courseware provided efficiencies that instructors did not have previously. Second, all course content was standardized so that every student in each course section confronted exactly the same material; material could not be

trimmed at the discretion of the instructor. Third, grading was standardized so that individual faculty could not curve the grades as they chose. Fourth, it is important to recognize that performance in these courses required students to pass from lesson-to-lesson by attaining high levels of mastery on all lessons, usually 90%, in addition to grades on exams. Mastery of each lesson was never part of the grading scheme prior to the change to adaptive learning as it could not be measured without the courseware. In the past, students could get a passing grade in these classes while having large gaps in their mastery of some content. ***Generally speaking, these changes made grading more stringent.***

Grades are reported below for Fall 2009 and Spring 2010 (Academic Year 09-10) prior to the adoption of adaptive learning systems. Grades also are reported for Fall 2012 and Spring 2013 (AY12-13), one year after the adaptive learning systems were adopted. In this early phase of adoption of adaptive courseware, student success varied across the three course and across semesters.

- Usually, grade performance is better in the Fall than Spring in all three courses in this early time period because more highly qualified first-time freshmen take the courses in the Fall.
- In MAT 110, grades definitely improved in the early transition to adaptive learning. Indeed, by AY15-16 (not reported in this table) student success reached enviable levels by national standards, **86% across both semesters**.
- The success rate in MAT 142 fluctuated year-to-year, but was relatively unchanged on balance over the academic years (combining the Fall and Spring semesters). Although unchanged, it must be emphasized the success rate remained quite high even with standardized grading and a doubling of class size.
- In contrast, performance in MAT 117 (College Algebra), the most difficult of the three classes, declined in most years, although allowance for standardized content, standardized grading and the 80% mastery requirement probably accounts for some of the decline.

SUCCESS RATE

	Pre-adaptive		**Post-adaptive**	
	F09	**Sp10**	**F12**	**Sp13**
MAT 110	69%	52%	83%	69%
MAT 117	69%	57%	63%	51%
MAT 142	82%	71%	83%	79%

A few problems became apparent in this time period. First, both instructor training and their experience in teaching in this manner were paramount to success. Turnover in instructors plagued the earliest years. Some instructors performed considerably above average, and some considerably below. Eventually, this was rectified as successful and experienced course coordinators took responsibility for monitoring, mentoring and training less experienced instructors. Overtime, a core of more permanent instructors were retained from year-to-year. There also were other changes that influence year-to-year student performance such as the change in the math placement exam and the use of i-courses. As a consequence, student success rates can and did fluctuate between years as these external factors changed. A more persistent problem was this was the dawn of the technological development in adaptive learning courseware, led by ASU. The technology was still catching up to the instruction throughout these early years; and MAT 117 was especially plagued by this problem.

Phase 2

Starting AY 2015-16, we began planning for substantial changes to our courseware, beginning with the transition to ALEKS (McGraw Hill) in MAT 117. MAT 142 will begin a transition to ALEKS in Fall 17. ALEKS makes possible some very important enhancements.

- The courseware for MAT 117 had not been updated significantly by the original vendor since it was launched. In contrast, the new ALEKS courseware is much more precise in terms of recommending content to students. This same courseware provides personalized learning paths to the many thousands of students in the GFA College Algebra course, to be discussed below. The previous courseware could not have managed a task of the magnitude of GFA.
- Our own instructional videos have been integrated into the ALEKS platform. Students also have access to a great deal of learning assistance from tutors to learning assistance in the classroom. Additionally, new short videos produced "by students for students" are used to provide real-time tutoring on specific topics around the clock.

The advantage of ALEKS is its superior capability to remediate not only within the course content, but also remediate with content that is pre-requisite knowledge below the starting level for the course. This led to a radical departure from the national practice. MAT110, foundational math, was eliminated in spite of the success in this course that started with a A-B-C rate at 66% prior to adaptive learning and finished above the 85th percentile. Now, students who would have placed into foundational math in the past enroll directly into the appropriate credit bearing courses, MAT 142 or MAT 117. ALEKS possesses the capability of assessing a student's mastery of content, topic-by-topic. If a student needs foundational remediation in any particular topic, ALEKS can deliver it as needed and when needed. Some students may need an entire semester of remediation. They would earn continuing credit (a Z grade) in their class and finish the course the following semester. Many students may need much less remediation and they can complete in one semester what would have taken two semesters in prior years. Additionally, students will not be placed into a remedial class. Studies find that remedial classes create a self-fulfilling feeling of failure; and for students insufficiently resilient, often lead to higher withdraw rates from the university.

Student success in terms of grades for AY 15-16 (pre-ALEKS) and AY 16-17 (post-ALEKS) are presented below for the three classes. Recall that by AY 16-17, foundational math had been eliminated and MAT 117 and MAT 142 now comprise what were three large-enrollment courses previously. Students who took MAT 110 in the previous year because of low placement scores (there were more than 1,200 of them) are now main-streamed into MAT 117 and 142. Once again, to keep comparisons consistent with the previous data, grades are reported for on-campus sections as the dominant option available to students when the transition to adaptive learning took place.

SUCCESS RATE

	Pre-ALEKS		**Post-ALEKS**	
	F15	**Sp16**	**Fall16**	**Sp17**
MAT 110	85%	87%	X	X
MAT 117	62%	64%	79%	77%*
MAT 142	80%	64%	80%	70%
Total enrollment	4,150	1,945	4,400	1,217

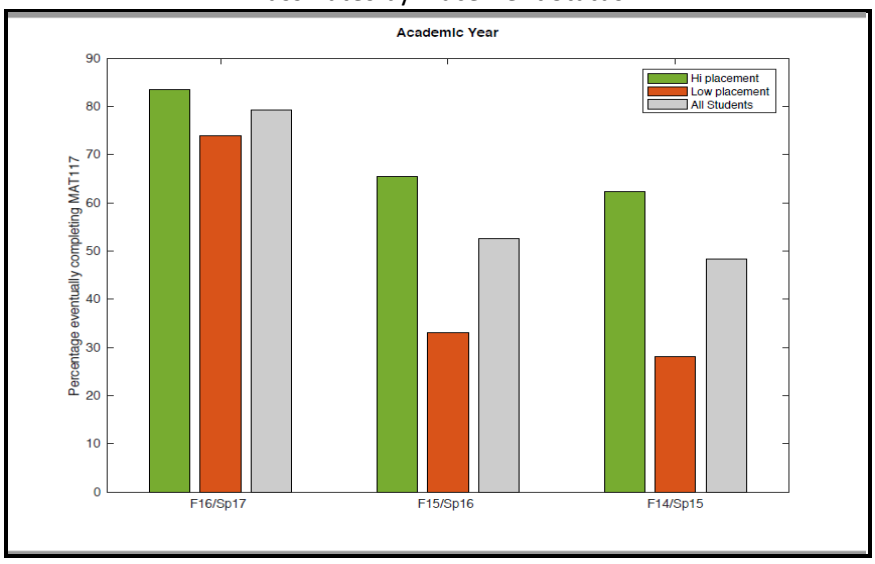
*Forecasted based on the expected conversion rate of Z to a passing grade

The results are transformational for MAT 117.

- Student success in MAT 117 jumped to 79% in Fall16 and is projected to achieve 77% in Spring17 if students successfully convert Z (continuing credit) grades to passing grades at the same rate as they did for Fall16; this in spite of having students who previously placed into foundational math main-streamed into the challenging College Algebra class.
- Student success in MAT 142 also improved over the combined Fall-Spring semesters, although MAT 142 still employs older adaptive courseware and has yet to be converted to ALEKS courseware. What is noteworthy is this success was achieved in spite of having students who previously placed into foundational math main-streamed into the course.
- Enrollment in what were three classes in Fall15 went from 4,150 to 4,400 as the three classes were collapsed into two in Fall16. But Spring enrollment fell from 1,945 in Spring16 to 1,217 in Spring17. This means significantly more students completed in one semester what many did over two semesters in previous years. This is an important step in achieving the goal to eliminate math as a "rate limiter" for student success in both STEM and all other areas of study.

Another consideration in achieving the goal to eliminate math as a "rate limiter" is to examine how students perform in the context of their initial preparation. The chart below shows the rate at which students passed the course based on preparation. Several things are noteworthy. Students previous to the migration to ALEKS completed the course at significantly lower rates, as already mentioned; but this is especially true for students with low placement scores. In previous years, students with initially low placement scores eventually passed this course only 31% of the time, about a 33 point gap compared to students with satisfactory placement scores. In AY16-17, those students passed the course at a rate of 74% while 83.5% of the students with satisfactory placement scores passed the course, substantially closing the achievement gap.

Pass Rates by Placement Status



Alternative measures of student success

Even these results understate the success of the courses. For instance, students can choose a W or Z grade in MAT 117 and not complete the course for reasons unrelated to class performance. The large majority choose a W or Z grade with the intent of completing the same course the next semester; and a significant number achieved this goal. But others drop the course because they change their major to one that requires MAT 142 instead of MAT 117. Still another segment of students start at ASU in the Fall semester but do not re-enroll at ASU for the Spring semester for a large number of reasons. They will not be able to convert to a passing grade by Spring. **The success rate in MAT 117 goes to 87% once adjustment is made for those who choose a Z or W with the intent of enrolling in MAT 142 in a new major or the intent of withdrawing from ASU entirely.** When Online students are included, the success rate is 83% in Fall16 after these adjustments. A final perspective on grade performance is to calculate the percent of students who enrolled in MAT 117 and received a D or E grade. That figure is only 3.2% for Fall16.

Place holder ACHIEVING COURSE SUCCESS RATES OF MORE THAN 80% MASTERY
As already indicated, the adaptive learning system can measure proficiency for each learning objective in the course. Often, a rule of 90% proficient is used. Show average proficiencies over all learning objectives for all students -- This would have to be only measured for students who complete the course.

2. THE FUTURE TRANSFORMATION OF ASU'S ADAPTIVE LEARNING PLATFORMS

Immediate steps

The first stage of course development using adaptive learning courseware at ASU involved three large enrollment courses, MAT 110, 117 and 142. As the Board's instructions were being designed to transform three courses, ASU eliminated MAT 110 and collapsed the original three courses into two, either MAT 117 or MAT 142, depending on the student's major. At the current time, success in the three courses, now collapsed to two, provide all of our data. However, further extensions and enhancements are being planned as next steps in the transformation of math education. First, MAT 142 is being converted onto the ALEKS platform in Fall 17 as a pilot in a few sections of the course; and converted entirely to ALEKS in Fall18 when the courseware is de-bugged. As it did for MAT 117, ALEKS will provide a superior adaptive learning experience for students in MAT 142; and it will provide superior measurements of proficiency on every learning objective for every student. Additionally, a pilot project teaching MAT 170, pre-calculus, is slated for Fall17. This will become another large enrollment class transformed to an adaptive learning platform. MAT 170 is an important pre-requisite course for many STEM students not yet prepared for Calculus. At the same time, pre-calculus is being readied for GFA using ALEKS, greatly accelerating course development across the ASU curriculum.

The next transformations

It will take much less time for other universities to catch-up to our existing stage of development in adaptive learning courseware than it took ASU to develop, launch & advance it. Our development was fostered by millions of dollars of grants from the Gates Foundation and the courseware was co-developed with technology companies or the technology units of publishers. The intent of the Gates Foundation, and certainly the goal of the publishers, is to disseminate the usage widely. It also is an ASU

goal. To this end, ASU is participating in a very large project managed by APLU to accelerate adaptive learning courseware among a set of large public universities. Additionally, adaptive learning courseware is a prominent discussion item among the large public universities in the University Innovation Alliance. Many of them are adopting the technique. Finally, some of our co-development partnerships with vendors normally return a revenue share back to ASU for co-developed courseware sold outside of ASU, enhancing our own incentive for widespread adoption.

Although catch-up is inevitable, plans are in place that will maintain ASU's leadership in the transformation of math education, a task assigned to ASU by the Board. The first development is the build-out of additional math courses in the Global Freshmen Academy (GFA) including pre-calculus and calculus courses. The GFA provides a sandbox unavailable to any other university.

- Extraordinary resources and talent from ASU's EdPlus are used to build GFA courses. This will maintain our course design efforts at the frontier.
- The resources also provide opportunities for EdPlus to experiment with different designs that extend what can be accomplished in digital learning environments.
- These courses make available massive amounts of detailed data on an equally massive number of learners. The data analytics that can be performed for learning science seem almost unlimited.

In its first year, the ALEKS based GFA College Algebra (MAT 117) attracted more than 50,000 learners. Of these, about 10,000 proved to be engaged students and more than 500 completed the entire course, mastering more than 90% of the curriculum. The amount of data coming from this course that can become available to learning scientists and course designers is beyond any scale previously encountered anywhere. Cumulatively, the 50,000 learners were tested on more than 1.5 million math skills and GFA students mastered more than 500,000 skills, more than 1,500 new math skills learned each day. The lessons learned by course designers in the GFA class from this data are often migrated to other learning platforms, both on-campus and on-line.

The course is led by a single instructor, supported by a team of undergraduate coaches supervised by the Undergraduate Academic Success Programs office. The coaching team provides scalable support and advice, creating instructional video content "on the fly" to answer student questions and providing targeted advice to students through ASU'S Compass learning support system. Compass allows the instructional team to target the "just-in-time" delivery of learning content to specific groups of students identified through combinations of demographic and performance based characteristics. As in the case of data, some of these innovations in learning support that are tested in GFA can be (and have been) migrated to classes delivered both on-campus and online.

In May 2017, GFA added a pre-calculus course, also based on ALEKS, a precursor to installing adaptive learning in this course on-campus. Supported by the same instructional team, GFA pre-calculus is off to a solid start, attracting about 1,000 new learners every week. First-year calculus courses directed at Engineers (MAT 265) and Business majors (MAT 210) are currently under development, and are expected to launch in 2018. The development of these classes for GFA also will accelerate the development for delivery on-campus and on-line.

The adaptive leaning courses in GFA and elsewhere also play an important role in ASU's global leadership for access to higher education. The math innovation (and other courses) will tackle some of the greatest barriers to success in higher education and or STEM majors. This is true globally as well as locally. The GFA courses provide access to college level courses for students around the world who have

no other access; or students who need alternative access. An example of the latter is the "Earned Pathway" for admission to ASU. A substantial number of potential students do not meet admissions requirement, including Starbucks employees. They can earn admission into ASU by passing GFA courses. Additionally, ASU Prep Digital embeds personalized, adaptive technology in all of their mathematics courses for all of their students, expected to be in the tens of thousands. This non-linear, adaptive approach gives high school students agency in their math education. While mastering individualized objectives, students also collaborate with peers in weekly mathematics challenges and engage in live teaching sessions with their instructors

Another "next step" in the evolution of adaptive learning in math will be "connected courses". A RFP has been completed seeking developmental partners to build courses that talk to each other. Success in many courses depends on pre-requisite knowledge brought forward from previous courses. This is most apparent in math classes and classes that depend on mathematical knowledge. For instance, the first calculus course for engineers depends on knowledge of pre-calculus. The engineering calculus classes that follow depend sequentially on the prior calculus classes. Likewise, the first calculus class for business depends on college algebra. Often students stumble because they lack adequate recall of knowledge from prior classes. Connected courses solve this by remediating/refreshing content knowledge wherever and whenever the courseware detects the student needs refresher content from previous courses – courses will "talk" to each other. It does not stop there. Physics beyond general education requires proficiency in calculus. Thus Physics must also "connect to" calculus. An Engineering course must connect to the physics course which must connect to a calculus course; and so forth. The RFP contains the possibility of connecting the courses in the lower division engineering core, including math classes; and the lower division core for business including business calculus. Discussions have begun to select co-developers to build adaptive and connected courses in calculus for both Engineering and Business.