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March 23, 2017

CHANCELLORS

Dear Colleagues:

Improving student success is at the core of our University principles. Campuses across the UC system continuously explore using evolving technologies alongside effective methodologies to enhance teaching and student learning. Recently, three campuses conducted year-long pilot studies on using adaptive learning technology to improve student success in entry level mathematics and chemistry. Each of the pilots showed positive results.

UC Davis, UC Santa Barbara, and UC Santa Cruz each sought to address an issue that many entering freshmen face – the need to fill foundational knowledge gaps in order to place well and succeed in first-year math or chemistry.

Through their implementation of summer bridge programs using the ALEKS adaptive learning system, the campuses saw higher placement and improved student performance in these courses. They also showed that the students who participated generally did as well as other students who initially placed into the course without the foundational summer help. One campus, UC Santa Barbara, provided additional support using ALEKS during the academic year, yielding positive results as well.

A report highlighting the 2015-2016 pilot findings and recommendations by the three UC campuses is attached as a PDF.

I encourage you to consider the findings and recommendations outlined in this report and decide what conversations you might have at your campuses to advance meeting the needs of your students in their pursuit of academic success.

Yours very truly,


Janet Napolitano
President

Attachment

cc: Executive Vice Chancellors and Provosts
Provost Dorr
Undergraduate Deans

UNIVERSITY
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Adaptive Learning Technology Pilot Report

December 2016

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INTRODUCTION

This document presents a 2015–2016 pilot study at the University of California (UC) exploring the use of adaptive learning technology, in this case the Assessment and LEarning Knowledge Spaces (ALEKS) system, to enhance student success and improve instruction. Following an overview of the technology and the study’s premise, the report presents detailed accounts of the campus research groups’ approaches and findings.

Three UC campuses participated in this pilot, which originated as one of the programmatic commitments made by UC in association with the governor’s 2015–2016 budget. A UC Davis research team agreed to lead the project, with research teams from UC Santa Barbara and UC Santa Cruz also participating.

The UC Davis team, based in that campus’s Center for Educational Effectiveness, had begun investigations in this area related to mathematics and sciences courses. Research groups from both UC Santa Barbara and UC Santa Cruz had also identified the potential for adaptive learning technology in these disciplines. Each of the campus groups was motivated to participate in this pilot to address a common challenge facing a segment of incoming freshmen — that they are often unprepared for the rigors of entry-level calculus and chemistry courses. On some campuses, these students place into “workload” courses that address basic concepts but do not count as credit toward a student’s degree; on others, students place into developmental courses that give credit. In either case, these students fall behind their freshmen cohorts in their first year. Persistence was also a concern for campuses, as many students either drop these courses or fail to earn a for-credit grade. All three research groups also suspected that 1) these students do not stay in Science, Technology, Engineering and Mathematics (STEM) disciplines, and 2) they may experience a delay in time to degree as a result of falling behind.

Each campus research group had experience with adaptive learning within the context of its own campus. And each campus had experience with ALEKS, a content and assessment platform that focuses on mathematics and science content mastery. Thus, ALEKS became the adaptive learning technology component used in all three pilots. Each campus team implemented the ALEKS system to achieve its individual research goals.

ADAPTIVE LEARNING

The concept of adaptive learning is not new. In fact, good teaching practices have long embraced the concept — by changing the instructional approach or the learning content to address students' individual struggles or gaps in learning. In the last 25 years, numerous educational technologies and software systems have been developed with the aim of monitoring student performance and addressing student learning gaps across academic disciplines. More recently, given advances in technologies that apply elements of cognitive research to student learning, the number of software systems purporting to be adaptive and to show positive learning outcomes has increased. Educators now face a growing number of options for technology products that present different, sometimes confusing, claims about learning and that pose significant organizational impacts and costs-of-ownership. Educators want to understand how the systems work and how they help students learn. But educators and technology suppliers have not been able to find or agree upon a common definition of adaptive learning.

In 2012, the Bill and Melinda Gates Foundation (Gates) gathered a group of university leaders from across the U.S. to discuss adaptive learning and the technologies that support it. Believing that adaptive learning showed potential to assist college students in earning their credentials more efficiently, Gates convened representatives from the University of Texas at Austin, American Public University, the Kentucky Community and Technical College System, and the American Association of State Colleges and Universities, among others. The gathering generated a Gates-funded study of adaptive learning and technology in higher education. Education Growth Advisors, now Tyton Partners, completed the initial comprehensive study and, with continued support, returned to the subject in 2015. They sought to understand how adaptive learning in higher education had changed since the initial study and how the changes might affect the future adoption of such technologies. Having gathered qualitative interviews with leaders from more than 20 institutions and survey responses from 35 suppliers of adaptive learning solutions, the group defined adaptive learning:

“Solutions that take a sophisticated, data-driven, and, in some cases, nonlinear approach to instruction and remediation, adjusting to each learner’s interactions and demonstrated performance level and subsequently anticipating what types of content and resources meet the learner’s needs at a specific point in time.”

The result, *Learning to Adapt 2.0: The Evolution of Adaptive Learning in Higher Education*, (2016) revealed five emergent themes across institutions of higher education. The first theme is

that there has been little change in the ability of institutions to move from pilot to broad implementation across the institution. This is important to understanding the complexities of implementation-to-scale. While adaptive learning has made significant leaps in feature growth, and has been shown to be relevant to competency-based education (two of the five themes), institutions face many difficult challenges that relate to integration of such systems into existing institutional infrastructure and to the organizational and academic workflows of the institution. These challenges are significant, and often costly.

In 2016, Pearson Learning released *Decoding Adaptive*, a report by EdSurge, an organization founded in 2011 with the purpose of connecting educators and educational technologists to information and research about what technology could do to support teaching and learning. The report defined adaptive learning and described various adaptive tools and systems. In this report the researchers asserted a definition of adaptive learning:

“... Digital tools ... that can respond to a student’s interactions in realtime by automatically providing the student with individual support.”

These two recent and significant endeavors agree on some common characteristics of adaptive learning:

- Individualization
- Adjustment to the learner’s interactions and performance, using data
- Adjustment made in real time
- Multiple pathways, potentially nonlinear
- New content and resources relevant to the individual’s demonstrated need

At the same time, both recognize the complexities institutions face in evaluating and implementing adaptive learning systems within the academic and technology components of the institution’s organization.

WHAT IS ALEKS?

The Assessment and LEarning in Knowledge Spaces (ALEKS) system was developed through research in mathematical cognitive science known as Knowledge Space Theory, initiated in the 1980s by professor Jean-Claude Falmagne at New York University (NYU) and the University of California, Irvine, and professor Jean-Paul Doignon at the University of Brussels. According to

ALEKS' published information, "the complex educational software based on Knowledge Space Theory is capable of efficiently and accurately assessing knowledge in various disciplines." The system assesses the student's "knowledge state" and creates a list of what the student is ready to learn. By monitoring in real time the state of the student's knowledge, ALEKS continuously offers students the content they are ready to learn.

Each student begins with an assessment of current course knowledge wherein the system chooses each question based on the response to the previous one, presenting a highly variable, individualized assessment for each student. ALEKS develops a view of the student's knowledge state, which is represented visually in a multicolored pie chart.

After the assessment and the presentation of the pie chart, the student enters the learning mode. The student chooses a topic (from a selection based on prerequisite knowledge demonstrated in the assessment) and works through practice problems that teach the topic. The student consistently must get the practice problems correct to achieve mastery before moving on to another topic. The pie chart represents the student's growing mastery of topics and as the student progresses, he or she achieves a more complete pie chart. Periodically, ALEKS will reassess topics to ensure they are retained, and the system continues to adjust to the student's learning.

While ALEKS offers a number of products, the UC research teams chose two distinct product types for the Adaptive Learning Technology Pilot. *ALEKS PPL* focuses on Mathematics Placement and Preparation (UC Santa Cruz), and *ALEKS HE Science* provides courses to prepare for general chemistry and supports each chemistry course throughout an academic sequence (UC Davis and UC Santa Barbara).

HOW WAS ALEKS IMPLEMENTED?

ALEKS was implemented at each of the campuses in different ways during summer 2015, fall quarter 2015 and winter quarter 2016 to address each campus team's specific research questions related to instructional support for students' learning and achievement in beginning chemistry and mathematics.

All three campus teams employed the ALEKS system during the summer, either to prepare freshman students to take an entry-level math or chemistry course (to refresh and build missing knowledge topics) or as a placement or re-placement mechanism that would accomplish the

same objective while effectively reducing enrollment in prerequisite workload courses. Campus teams then tracked student performance in the courses they took during the fall quarter and their subsequent performance in the next course in the sequence during winter quarter. To further support student success, during the fall quarter 2015 and winter quarter 2016, UC Santa Barbara employed ALEKS in the course as homework support.

In the pilot, ALEKS did not comprise the whole of an academic course, although other campuses may use the system in that way. Instead, the student either 1) prepared for the academic course, 2) placed or re-placed into the course, or 3) used ALEKS as support during the academic coursework.

Members of the three participating campus research teams met on several occasions during the academic year to share their study goals, approaches, experiences, tools and methods. All identified positive results (some of more significance than others) as well as challenges to using ALEKS in the learning environment. These details follow.

UC DAVIS PILOT

PILOT TYPE	Preparation and Placement
RESEARCH TEAM	Marco Molinaro, assistant vice provost for Educational Effectiveness Catherine Uvarov, former postdoctoral fellow Alberto Guzman-Alvarez, former analyst With support from the provost and the Department of Chemistry
CAMPUS COURSES	General Chemistry 2A (CHE 2A) and Work Load Chemistry prep course (WLD 41C)
ALEKS COURSES	Summer Prep for General Chemistry (SP-Chem)
NUMBER OF STUDENTS IDENTIFIED	1099 (but not all invited to participate)
NUMBER OF STUDENTS COMPLETED	274 of 551

Summary

In collaboration with the UC Davis Chemistry Department, the researchers conducted a pilot study of an online summer preparatory program for chemistry using ALEKS. Aimed at incoming freshmen, the online chemistry preparation was used as an alternative to the placement exams and/or workload chemistry course that would normally satisfy the prerequisite requirement for enrolling in CHE 2A for the 2015–16 academic year. Participation was optional, by invitation. Of note: During the study, students received timed emails from research staff regarding

participation and deadlines, but they essentially worked on their own without any faculty or TA intervention. Students' successful completion of the summer preparatory course (achievement of pie at 95 percent or better) fulfilled the prerequisite requirement to enroll in CHE 2A without their taking a placement exam or the in-person preparatory chemistry course WLD 41C, for which students do not earn academic credit.

Key research questions and analysis

Question 1	Conclusions
Does using ALEKS as a preparatory course during summer help students to succeed in General Chemistry 2A?	<ul style="list-style-type: none"> • Students appear well-prepared to succeed in the General Chemistry 2A course, and they do as well as students who placed into the course without ALEKS. • Students appear to do better than those who took the workload course WLD41C or who repeated the course.

ANALYSIS

Using scores on pre- and postassessments and the common final exam as primary measures of student performance, the researchers looked at data for fall quarter 2015 and winter quarter 2016 as a combined data set. Comparison groups were identified and were narrowed to include only 1) those who placed directly in General Chemistry 2A, 2) those who completed ALEKS Summer Prep for General Chemistry and placed into and took the course, 3) those who completed WLD 41C and passed, thus entering General Chemistry 2A as prepared, and 4) those who were repeating General Chemistry 2A (with no other interventions or re-placements).

FINDINGS

The researchers found no statistically significant differences in overall course performance between the students who directly placed into General Chemistry 2A and those who completed ALEKS Summer Prep and placed in the course. However, they found significant gains in pre- and post- states between the students who finished ALEKS SP-Chem and students who passed the WLD 41C course. Overall, students who finished ALEKS SP-Chem in the summer gained 6.9 percentage points more than those who took the WLD 41C course first. The gains are more significant between the ALEKS SP-Chem student and those who repeated the course — scoring 11.5 percentage points more between pre- and post-states. Using final exam scores, a more direct measure of student course grade outcome, the gain was a bit higher: 8.81 and 13.51 percentage points, respectively.

When using underrepresented minority (URM) status to evaluate whether an achievement gap persists between student populations, the researchers found no significant difference between the students who directly placed in General Chemistry 2A and those who completed ALEKS SP-Chem in the summer. Similar gains using final exam data exist with URM students who completed ALEKS SP-Chem and those who completed the WLD 41C course first — with a 10.3 percentage-point gain for the ALEKS SP-Chem students.

CONCLUSIONS

In general, students willing to utilize ALEKS over the summer appear well-prepared for CHE 2A success, perform as well as those students who placed into the course without utilizing ALEKS, and grade better than those students who take WLD 41 first or who repeat CHE 2A without any other intervention. The effect appears to be that more students are able to take the credit-bearing course in the first term offered, rather than being required to enter workload (WLD) courses. These conclusions hold true for URM students as well.

Question 2	Conclusions
Are certain student populations utilizing ALEKS more than others?	<ul style="list-style-type: none"> • While there are differences in the percentages of students by college who started and completed ALEKS in the summer, no clear reason is evident from the data. • Both low-income and URM students have significantly lower completion rates than students not identified as low-income or URM.

ANALYSIS

The pilot team checked how students were using ALEKS over the summer, and clustered students based on their usage patterns. The team performed hierarchical cluster analysis in order to determine if there were correlations between usage patterns and subsequent performance in CHE 2A, and if any demographic differences appeared in the clusters. The researchers formed clusters around: 1) overall change in the student's pie mastery, 2) how early in the summer the student reached maximum pie mastery, 3) the rate of the student's pie mastery change, and 4) the degree to which the change in pie mastery was gradual or intermittent. They also applied nine characteristics, including time spent, daily pie mastery change, days worked to achieve mastery, days to maximum pie mastery, days spent in ALEKS, initial assessment from ALEKS and SAT score.

For summer usage of ALEKS, the team analyzed 424 student results, placing students in one of 10 clusters. Very small sample sizes in some of the clusters prevented robust statistical analysis

of performance. They used visualization software to show cluster performance in mastering pie over time during the summer.

Student populations included students by Colleges, including Letters and Sciences, Engineering, Biological Sciences, Agriculture and Environmental Sciences; and demographics, including URM, low-income, first-generation and female.

FINDINGS

The researchers found that students who completed ALEKS in the summer took diverse approaches to gain pie mastery, even given similar SAT (total) and initial assessment scores. This can be attributed to the nature of the ALEKS system, which is highly individualized and based on adaptive response. Many of the students who completed ALEKS succeeded by gradually working on mastery throughout the summer.

When looking across the student populations, with approximately equal percentages from each college (with the College of Letters and Sciences having a slightly lower percentage of students), the percentage of engineering students who completed ALEKS was much higher than that of students in other colleges. Completion by engineering students was 64 percent of that school's total population, with an average completion by student at other colleges at 53 percent.

While one of the pilot goals was to narrow the performance gap between student populations, when looking at demographics the researchers found a disparity between the demographic population and the total population who started and completed ALEKS. For instance, for URM students compared to those not from the URM group, 41 percent of URM students started and finished, while 65 percent of non-URM students did. Among low-income students, 48 percent started and finished, while 62 percent of non-low-income students did. And for first-generation students, the percentage difference was essentially the same, 48 percent completion vs. 63 percent completion for students not of that demographic status. Female students, on the other hand, had less disparity, at 55 percent of female students and 59 percent of male students completing ALEKS.

CONCLUSIONS

While there are differences in the percentages of students by college who started and completed ALEKS in the summer, no clear reason is evident from the data. And, when looking at the demographic populations and their differences in percentage that start and complete, the data sets were determined to be too small to draw meaningful conclusions. But the researchers

do note that URM students show significantly different completion rates compared to non-URM students. Factors that may explain those differences were not included in this analysis.

Question 3	Conclusions
What are the barriers of use (of ALEKS)?	<ul style="list-style-type: none"> • None of the potential barriers identified in the study were found to be significant.

ANALYSIS

Students who started ALEKS (and did not complete) and those who did not start at all were asked to select external factors that may have been impediments to starting or completing ALEKS SP-Chem.

A smaller group of students, comprising those who did complete ALEKS SP-Chem and those who chose to enroll in WLD 41, were given the MUSIC Model for Academic Motivation and STEM Identity survey to look into non-cognitive measures of persistence. The MUSIC Model survey measures across five constructs of motivation (empowerment, usefulness, success, interest and caring) and three constructs of STEM identity (identification, ability and career). In the survey, students rated on a 6-point Likert scale the degree to which they agreed or disagreed with a series of statements that may have contributed to not starting or not completing ALEKS during the summer. The researchers created density graphs of student ratings to compare the two groups across the constructs.

FINDINGS

The top reason that students reported for not completing ALEKS in preparation for the fall CHE 2A course was having achieved a passing score on the chemistry and math placement exams given at UC Davis. 47 percent of respondents reported this reason. The next-highest reason reported was lack of time, at approximately 30 percent. A drop to 16.7 percents clustered around such reasons as *felt confident in chemistry, didn't feel the summer course was necessary, or decided to take the WLD course instead of doing summer prep*. Other reasons, cited by 10.8–13.7 percent of respondents included *conflict with summer travel, family obligations, don't need to take chemistry, and job conflict*. Far fewer cited *lack of technology, summer program involvement, junk mail, or other*. Responses were not analyzed according to demographic status, such as URM or first-generation college student.

In the MUSIC Model for Academic Motivation and STEM Identity, overall, students who completed ALEKS SP-Chem and students who enrolled in WLD 41C gave both courses high ratings on all five constructs of motivation. In the Caring construct, ALEKS SP-Chem is only slightly higher than WLD 41C, likely due to two factors: 1) the nature of the WLD 41C course as

a face-to-face experience, and 2) the research team having sent periodic and personalized emails over the summer to the ALEKS SP-CHEM students. The researchers believe these may have contributed to an overall higher caring rating for the ALEKS SP-Chem course.

CONCLUSIONS

The researchers did not strive to connect students' reasons for not completing ALEKS SP-Chem to the results of the motivation and identity survey from some of the cohorts. Further, none of the barriers to completion have been found to be significant to overcome for more complete participation and more successful performance in CHE 2A.

Still, the researchers have determined (based on the finding that nearly half of the students did not take ALEKS SP-Chem because they successfully placed into the CHE 2A course) that the campus will not include this group in any future comparisons.

The UC Davis team did identify, however, that running a summer bridge program for incoming freshmen has several challenges. First, the students are not yet "fully matriculated," i.e., they have not entered the university as matriculated students for the fall, so they have not yet engaged in matters like self-identification (as needing accommodation or other support). Furthermore, these freshmen have not begun to enjoy the organizational structures the campus offers, such as academic advisement and financial aid, nor have they begun to develop relationships with their freshman-year faculty for support. The researchers did note that they tried to prevent possible barriers to participation, such as the lack of communication and support (addressed through the emails sent to students who began ALEKS SP-Chem), and the cost of ALEKS (typically the student's responsibility, but covered by the campus or department for the pilot).

UC SANTA BARBARA PILOT

PILOT TYPE	Preparation and Homework Help
RESEARCH TEAM	<p>Carl Gutiérrez-Jones, Department of English and associate vice chancellor and dean of Undergraduate Education (2015–2016)</p> <p>Linda Adler-Kassner, interim co-dean of Undergraduate Education and professor of Writing Studies</p> <p>Steven Velasco, director of Institutional Research</p> <p>Darby Feldwinn, Department of Chemistry</p> <p>Margarita Safronova, Department of Political Science</p>
CAMPUS COURSES	Chemistry 1A (CHE 1A)

ALEKS COURSES	General Chemistry (First quarter — with partial use in summer prep)
NUMBER OF STUDENTS IDENTIFIED	598
NUMBER OF STUDENTS COMPLETED	598

Summary

Earlier research by UC Santa Barbara chemistry faculty members revealed that many students entering the study of chemistry struggled with fundamental math and science concepts and had difficulty applying these concepts to problems associated with entry-level chemistry. UC Santa Barbara faculty elected to use ALEKS as a summer course prior to the beginning of the fall quarter 2015, and as a homework assignment during the term, alongside work within the CHE 1A course. The aim of UC Santa Barbara's pilot was to study the effect of using ALEKS on overall success in CHE 1A, a gateway course (one required in a number of majors), and to ascertain the degree to which ALEKS improved performance in CHE 1A.

Key research questions and analysis

Question 1	Conclusions
Does performance on the ALEKS initial assessment knowledge check administered in the first ALEKS summer course serve as a predictive tool for success in Chemistry 1A?	<ul style="list-style-type: none"> Completion of the ALEKS summer course has a significant and positive effect on students' final grades in CHE 1A.

ANALYSIS

The study population consisted of all students in Chemistry 1A in fall quarter 2015 with comparison groups for those who did complete the summer course and those who did not.

Results of summer placement, course grades of B- or above, and the final grade in CHE 1A were used as primary measures while controlling for a variety of academic preparation characteristics (such as high school GPA and SAT score) and demographic characteristics (such as gender, first-generation college status and socioeconomic factors). Success was defined as a grade of B- or above.

FINDINGS

The researchers found that the students who completed ALEKS assignments in the summer and who succeeded — earning a score of B- or better in CHE 1A — increased their probability of receiving such a score by 30 percent, when controlled for other factors. The data further suggest that the ALEKS summer course initial assessment is a significant predictor of success in

CHE 1A. The estimates indicate that for every one percent increase in ALEKS summer course topic mastery demonstrated in the initial placement, the probability of success in CHE 1A increases by nearly half a percent.

CONCLUSIONS

Completion of the ALEKS summer course has a significant and positive effect on students' final grade in CHE 1A.

Question 2	Conclusions
Do final grades vary among students who do and do not complete the prequarter assignment?	<ul style="list-style-type: none"> • Completion of the ALEKS summer course has a significant and positive effect on students' academic performance in CHE 1A.

ANALYSIS

To determine differences between final grades among students who completed or did not complete the summer course, the researchers calculated average and median final CHE 1A course grades. Using a 4.0 grade scale, the researchers did not correct for academic preparation or other demographic information.

FINDINGS

Students who completed the summer course received higher average grades than students who did not complete the summer course. While the group of noncompleters is only 10 percent of the size of the group of completers (56 students vs. 526 students), the researchers found nearly a grade-and-a-half difference between the mean grades of summer completers and non-completers of the summer course: 2.61 to 1.21, respectively. The median grades showed an even larger difference: 3.00 to 1.00. However, the researchers note that much of the difference in average grades is likely to be explained by prior academic preparation and other characteristics of students. Thus, the researchers looked for net impact when considering those other variables. Still, results suggest that students who complete the summer course in ALEKS receive an estimated .79 higher grade than students who do not complete the summer course.

CONCLUSIONS

Again, the researchers note that completion of the ALEKS summer course has a significant and positive effect on students' academic performance in CHE 1A.

Question 3	Conclusions
Does the use of ALEKS during the term, when incorporated into CHE 1A as homework help, contribute to students' abilities to develop the knowledge and study habits necessary for success in Chemistry 1A?	<ul style="list-style-type: none"> • There is very little evidence that use of ALEKS contributes to students' abilities to reflect on and develop their application of knowledge in CHE 1A.

ANALYSIS

The researchers examined the relationship between a Study Best Practices Index (SBPI) and metrics concerning a student's use of ALEKS in the fall quarter. The SBPI is based on closed-end responses to a self-assessment distributed to students during the midterm exam in CHE 1A. The index consists of self-reported practices and behaviors about the student's engagement in various activities that should lead to success in the course. The team used this index as a proxy for the practice of good study habits.

The researchers looked to determine whether or not the use of ALEKS (as measured by the number of topics learned per hour and total time spent in ALEKS) is associated with higher levels of SBPI.

FINDINGS

UC Santa Barbara researchers found no evidence that the ALEKS measures (topics learned per hour and total time spent in ALEKS) were related to the SBPI. In fact, when looking at other factors, specifically high school GPA, a definite positive association between GPA and higher levels of SBPI was found. No other controls for academic preparation showed any significant effect.

CONCLUSIONS

The researchers indicated there is very little evidence that use of ALEKS contributes to students' abilities to reflect on and develop their application of knowledge in CHE 1A.

Question 4	Conclusions
Does reflection on learning via ALEKS (and other course activities) as it is incorporated into CHE 1A contribute to students' abilities to develop and apply knowledge within Chemistry 1A?	<ul style="list-style-type: none"> • Only the identified missed questions (on the midterm) appear significantly related to a student's ability to develop and apply knowledge in the course. • This effect is negated when controls such as prior academic achievement, high school GPA and SAT score are applied.

ANALYSIS

For this question, UC Santa Barbara researchers used open-ended questions incorporated into the midterm self-assessment given to students taking CHE 1A. Students were asked to: 1) identify the problems they had seen before, but which they missed on the midterm exam, 2) say whether or not they had studied the missed material prior to the exam, and 3) discuss how they would change their study habits to ensure a better grade on future exams. The team hypothesized that use of and reflection on learning contributed to students' abilities to develop and apply knowledge and correctly answer questions from ALEKS embedded in the final exam.

FINDINGS

According to UC Santa Barbara researchers, the ability to identify and reflect on practices and processes like those listed above are associated with metacognitive development, or the ability to consciously recognize one's own processes and actions in a learning context and to make decisions about learning in that context based on recognition. Metacognitive awareness has been identified as important for learning success.

The researchers coded students' responses into the three dimensions of: 1) identified missed questions, 2) studied missed prior, and 3) changed habit as a result. Although 285 students participated in the course, not all of the students responded to the questions, which the researchers point out limits the utility of the findings.

CONCLUSIONS

The researchers concluded that only the *identified missed questions* (on the midterm) dimension appears significantly related to a student's ability to correctly answer the ALEKS-related problem on the final exam. However, this effect is not present when controls for prior academic achievement, such as high school GPA and SAT score, are put in place. The other dimensions showed weak and negative correlations to performance on the final exam.

Question 5	Conclusions
For students in the lowest quartile of the ALEKS assessment, what correlation, if any, exists between students' ALEKS use, performance on particular exam questions and students' final grades?	<ul style="list-style-type: none"> The researchers found completion of the ALEKS summer course and use of ALEKS in the fall quarter to be significantly related to the achievement of higher grades in CHE 1A for students in the lowest quartile.

ANALYSIS

To explore the impact of ALEKS use among the lowest quartile students, UC Santa Barbara researchers used a model that allowed them to assess the estimated change in students' CHE 1A grade based on a variety of explanatory factors, including ALEKS summer course completion, previous academic performance and demographic characteristics. In the summer 2015 ALEKS pilot, 137 of 594 students were in the lowest-quartile initial assessment. The lowest-quartile students achieved 35 percent of topics known in the initial assessment compared to 59 percent for all other students. 80 percent of these students also completed the ALEKS summer course compared to 90 percent of all students. In all, lowest-quartile students learned fewer topics per hour and spent more time in ALEKS.

FINDINGS

Students who completed the ALEKS summer course had a higher average CHE 1A grade than students who did not complete the course, representing a statistically significant correlation between final grade and completion of ALEKS during the summer. Further, students in the lowest quartile are estimated to have an average grade of .45 higher if they completed the ALEKS summer course compared to those who did not. The strongest predictor in the models for lowest-quartile students, similar to the models for all students, is the number of topics learned per hour during the fall. And, for students in the lowest quartile, while controlling for previous academic performance and demographic characteristics, there continues to be a positive and statistically significant relationship between topics learned per hour and final grade in CHE 1A.

CONCLUSIONS

Among the least prepared students in the lowest quartile of the ALEKS summer course initial assessment, the researchers found completion of the ALEKS summer course and use of ALEKS in the fall quarter to be significantly related to the achievement of higher grades in CHE 1A. The researchers indicate this to be a very positive result, providing evidence that the chances of success can be raised through the use of innovative tools and interventions such as ALEKS.

UC SANTA CRUZ PILOT

PILOT TYPE	Preparation and Placement
RESEARCH TEAM	Jaye Padgett, Department of Linguistics and interim vice provost for Student Success Debra Lewis, Department of Mathematics

	Julian Fernald, director of Institutional Research, Assessment and Policy Studies
CAMPUS COURSES	Math 2 (College Algebra), Math 3 (Precalculus), Math 11A (Calculus with Applications), Math 19A (Calculus for Science, Engineering and Mathematics)
ALEKS COURSES	ALEKS Placement, Preparation and Learning in Mathematics (ALEKS PPL)
NUMBER OF STUDENTS IDENTIFIED	3974 (3,625 entering freshmen + 349 transfers/other)
NUMBER OF STUDENTS COMPLETED	2,686 (took ALEKS placement; many did not need any of these courses)

Summary

UC Santa Cruz piloted the use of ALEKS PPL in the summer to allow incoming students to place into and take more advanced courses in math than they otherwise would have. The pilot's main goal was to shift incoming freshmen enrollments upward from more preparatory or developmental courses to the more college-ready courses, without jeopardizing students' performance in math.

Key research questions and analysis

Question 1	Conclusions
How many students took the assessment more than once? How did their placement score change? Did the pilot succeed in shifting enrollments to a higher math course?	<ul style="list-style-type: none"> • More students took more advanced classes without endangering their academic success. • Enrollment in the lower level Math 2 course in fall 2015 was 49 percent of what it was in fall 2014.

ANALYSIS

Based on their initial placement score with ALEKS PPL, students were encouraged to continue in ALEKS PPL and retake the placement assessment, some taking the assessment a second or third time. Of the total number of students who took the ALEKS PPL placement, 771 retook the exam at least once (of whom 722 were entering freshmen). The researchers removed students who placed into the highest-placement tier (since these students could have no incentive to reassess), finding 32.6 percent of all students and 35.1 percent of entering freshmen reassessed. The researchers looked further at the students' re-placement tiers, since these tiers would indicate the mathematics courses at UC Santa Cruz for which the student would be eligible. Of the 722 entering freshmen who retook the placement, 83.8 percent improved by at least one tier. The researchers then compared the historic enrollments and course completions for the first two math courses, Math 2 (College Algebra) and Math 3 (Precalculus) from the

2011–12 academic year through the 2015–16 academic year using the summer pilot of ALEKS PPL as a pivot point to check its impact on enrollment.

FINDINGS

While the numbers of students who completed Math 2 and Math 3 courses increased each year between the 2011–12 and 2014–15 academic years, after introducing ALEKS PPL as a replacement mechanism in the summer of 2015, researchers noted a significant decrease in the numbers of students who took those courses through the 2015–16 academic year.

The researchers further examined fall 2014 and 2015 performance data in all the mathematics courses affected by the introduction of the ALEKS PPL placement mechanism to determine if there was an effect on the pass rates in these courses. The researchers noted a dramatic overall shift in students from more introductory to more advanced math courses. They noted that performance has not shifted dramatically overall, citing that pass rates in three of the five courses rose while they fell somewhat in two of the courses (Math 3 and Math 19A).

CONCLUSIONS

The researchers concluded that the pilot was successful in getting more students into advanced classes without endangering their academic success. The researchers do note that other factors may have impacted enrollment shifts. For the cohort of students who typically take college-level algebra (Math 2) — entering freshmen — there was a 10 percent drop in the size of the incoming class by 419 students (from 4,037 in fall 2014 to 3,618 in fall 2015). Yet enrollment in College Algebra decreased by 51 percent from fall 2014 to fall 2015. And, there were increases in enrollment in the higher-level math courses.

Question 2	Conclusions
<p>Some students initially placed into course X but re-placed into a higher course Y after working within ALEKS PPL to improve. Are the outcomes for these students as good as they are for those who placed initially into course Y? How did these two groups compare in a subsequent math course?</p>	<ul style="list-style-type: none"> • Students who re-placed into a course after initially placing lower generally did as well as students who initially placed into the same course. • Students who re-placed into a fall course after initially placing lower did as well in a subsequent winter course as students who initially placed into the same fall course.

ANALYSIS

The researchers looked at performance in three courses: Math 3 (Precalculus), Math 11A (Calculus with Applications) and Math 19A (Calculus for Science, Engineering and Mathematics), first comparing the group of students who re-placed into the course via ALEKS PPL assessment

with those who initially placed into the course. They sought to determine if there was a significant difference in student performance overall in the course.

To address the question of how well the students who re-placed fared over time, the researchers also examined factors that predicted success of these placement groups in subsequent math courses — using these course sequences:

Math 3 (Precalculus) → Math 11A (Calculus with Applications)

Math 3 → Math 19A (Calculus for Science Engineering and Math)

Math 11A → Math 11B (Calculus with Applications, course 2)

Math 19A → Math 19B (Calculus for Science, Engineering and Math, course 2)

The team examined student performance outcomes in each sequence and their group as having placed initially or re-placed after ALEKS PPL.

FINDINGS

When taking certain demographic factors into account, such as URM, gender, first-generation status and Pell Grant-recipient status, the researchers found no significant difference in course grade or pass rate between the group who re-placed and the group who placed into the course initially. In fact, the researchers note that the strongest predictor of success is prior academic preparation as measured by SAT math score and high school GPA. This held true for Math 3 and Math 11A. For Math 19A, while the findings revealed that re-placement did contribute to predicting the final grade, it was not as strong a predictor as the math SAT score or high school GPA.

When looking at how students fared over time, in subsequent courses, the researchers found that students' group placement was of no consequence to successful performance in later courses. Students who worked their way up to Precalculus placement via ALEKS PPL did as well in the next math course as those who placed into Precalculus to begin with, all else being equal. The same is true for students who took Calculus with Applications or Calculus for Science, Engineering and Mathematics. From the researchers' perspective, this is a positive finding that supports the overall goal of helping students gain in time-to-degree without sacrificing academic performance.

CONCLUSIONS

The UC Santa Cruz researchers concluded that ALEKS PPL was helpful to those students who did retake the placement and who placed higher, thus taking and generally succeeding in the

higher-level math course. And, when continuing in the mathematics sequence, students who re-placed continued to do as well as those who initially placed into the same course.

Question 3	Conclusions
How do outcomes depend on placement scores in ALEKS PPL, both initial and final, or on the amount of time spent in ALEKS PPL?	<ul style="list-style-type: none"> • Researchers did not find that improved performance in the math courses was associated with more time within ALEKS PPL. • The student's score was only weakly (initial score) or not associated (re-placement score) with improved performance in the math courses.

ANALYSIS

The UC Santa Cruz research team wanted to explore whether or not the amount of time spent in ALEKS PPL helped predict the final course grade, and whether the student's score after replacing (initial score vs. re-placement score) helped predict the final course grade. The researchers examined the contribution of each of these factors as well as that of the SAT math score to final grades in Precalculus (Math 3), Calculus with Applications (Math 11A) and Calculus for Science, Engineering and Math (Math 19A).

FINDINGS

With the Math 3 course, the researchers found that the best predictor of final grade was the student's SAT math score, accounting for 37 percent of the variance in final course grade point. The next best predictor, at seven percent, was the time spent working in ALEKS PPL to re-place. However, time spent working in ALEKS PPL before placement was negatively associated with the final course grade. Further, the student's initial placement score accounted for only two percent of the variance, and the final placement score did not contribute to any prediction.

An analogous analysis for Calculus with Applications (Math 11A) and Calculus for Science, Engineering and Math (Math 19A) found that only a student's initial placement score within ALEKS PPL helped to predict the final course grade, though accounting for only 13 percent (Math 11A) or eight percent (Math 19A).

CONCLUSIONS

The research team concluded that a student's prior academic preparation, as represented by the SAT math score and/or an initial placement score, explains most of the final course grade. UC Santa Cruz researchers did not find that improved performance in the math courses was associated with more time within ALEKS PPL or with a student's score in ALEKS PPL after re-placing.

Going further, the researchers stated there may be many reasons that students may take longer working within ALEKS PPL, not all of which imply an advantage, and some of which are clearly beyond the control of the ALEKS system to address (such as anxiety about taking the next assessment or lack of confidence).

The researchers noted one significant challenge in that students work within ALEKS PPL on their own, and the environment in which they work is not controlled, nor was there faculty mediation from a learning perspective.

SUMMARY OF FINDINGS

Overall, each of the campuses involved in the Adaptive Learning Technology Pilot find that when ALEKS is used by students as it is intended — with an established achievement goal or pie mastery level, and with student persistence toward that goal — results are positive in relation to a student’s overall performance in the course to which it is applied. In some cases, the same positive results are evident in at-risk populations, such as URM, low-income and first-generation students. While those populations may demonstrate slightly lower performance results, the results are still positive within the overall demographic group.

However, ALEKS is not a “plug-and-play” panacea for poor student performance in these selected math and chemistry courses. When implemented alongside a course during the academic term, it does require faculty or TA monitoring and appropriate communication with students about their learning and their performance, regardless of how they are achieving results in ALEKS. This kind of support may differ depending on the implementation model put into place.

Using ALEKS as **preparation** for entry-level calculus or chemistry

The implementation of ALEKS as preparation for taking an entry level course typically occurs in the summer with incoming freshmen. Both UC Davis and UC Santa Barbara report positive results with students who completed their summer ALEKS assignment. For UC Davis, more students began CHE 2A than took WLD 41C (workload chemistry), one of the goals the campus wanted to achieve through summer preparation. And students who completed ALEKS SP-Chem performed as well as students who placed into the course initially and did not need to take ALEKS in the summer, and also performed significantly better than students who took WLD 41C, or who repeated the course without intervention. UC Davis ensured that students would not

have to pay for the ALEKS system and sent regular, personalized emails to students who started ALEKS throughout the summer.

For UC Santa Barbara, while students who completed the summer ALEKS course were 30 percent more likely to receive a grade of B- or above than students who did not complete the summer assignment, the average final grade for the CHEM 1A course in the fall was C+ compared to a D for those who did not complete the ALEKS assignment.

Using ALEKS to **place or re-place** at a higher level in entry-level chemistry or multilevel math sequences

In the UC Davis ALEKS summer program, successfully completing ALEKS and achieving a 95 percent or higher mastery met the prerequisites to place in CHE 2A. Of those who placed into the higher course given their summer ALEKS SP-Chem work, not all elected to take CHE 2A. Some elected WLD 41C. Still, as noted earlier, UC Davis found no statistically significant difference in performance between those students who initially placed into the course and did not take ALEKS and those who completed ALEKS successfully and then took the course. At UC Santa Cruz, there was a significant drop in the number of students needing to take Math 2 (College Algebra), one of the key goals of the pilot. And, re-placing into a higher level course, Math 3, did not negatively affect students' academic performance in the course. Still, the researchers did report a drop in the number of incoming freshmen, which could have contributed to some of that result.

Using ALEKS as **ongoing academic support** — homework — during an academic term

The UC Santa Barbara team implemented ALEKS during the term alongside the academic course. Their findings indicate that mastery of ALEKS topics during the quarter does have a statistically significant relationship to students' final course grades, and that this relationship is attributed to the number of topics learned per hour. Persistence with ALEKS and mastering topics appears to have continued positive impacts, even with lowest-quartile students.

CHALLENGES

As noted in the Gates report (2016), higher education institutions continue to face challenges to implement adaptive learning technologies at scale. The report noted that while many more institutions have begun to pilot adaptive learning systems during the last three years, few have transformed pilots into full-scale implementation. That effort is a significant one, requiring

institutional strategic objectives that take into consideration all facets of its organizational structure, from academics to research to technology to finance and accountability.

Some of the specific challenges noted by the UC researchers in conducting their pilots are related to summer implementation. In summer, the participating students have been *admitted*, but they have not yet fully *matriculated* at the campus. They have not yet fully engaged with the university, may not have received their financial aid or attended orientation, or may not have met with academic advisers or identified as needing accommodation of any kind when the summer program starts.

Thus, a key challenge for summer programs is coordinated communication at the university and with the student. The campuses noted the need for timely and informative communication with students through channels with which they engage during the summer, such as Student Affairs and Academic Advisement. Campuses noted that collaboration with these groups and transparency regarding the goals of the summer prep and placement programs need to be formalized so that appropriate and appropriately timed communications to students encourage their participation and ultimate chances of success in the summer program and, thus, their fall courses.

Another challenge the campuses face is the cost of the ALEKS system. At many campuses, ALEKS system costs are passed on to the student as “course materials fees.” And these fees vary based on the campus and the length of time the student will use the system (from \$35 to access the system for a term to nearly \$100 to access for two years). Costs can be a challenge for students and add to the overall cost of materials across the academic year. UC Santa Cruz found a method to pay for ALEKS costs without passing fees on to the student. With a summer program, many students who have been identified as participants in ALEKS have not received their financial aid packages in time to support summer usage. In the case of UC Davis, the researchers made arrangements with the vendor to delay the billing for usage until the beginning of the academic term, when students received their financial aid.

Regardless of usage in the summer or during the academic year, cost in general is a challenge because it raises institutional concerns about students and the fees they are required to pay. At times, discussion of passing costs to students can be controversial at a campus or within departments. Some think that the campus passes entirely too many costs on to students and that students are burdened by textbook and eTextbook fees, as well as technology fees. In this context ALEKS represents another cost to students, in addition to the course materials fees they pay for the course and the technology fees they pay for the term.

While none of the researchers indicated any known issues with students in their pilots related to accessibility, the fact is that the ALEKS platform is not completely accessible. It does not meet ADA requirements, Sections 504 and 508, nor World Wide Web Consortium (W3C) and Web Content Accessibility Guidelines (WCAG) version 2.0, which the federal government requires. Current screen-reader technology (used by blind students to “read” the text on the screen) cannot translate certain mathematical and scientific formulas nor content that is highly visual in nature. While students who use ALEKS may make requests for accommodations through their Students with Disabilities centers, students still may have difficulty completing the content within ALEKS in either reasonable or timely fashion. Certainly this could pose difficulty for summer bridge students who have not yet matriculated nor identified to their campus as requiring accommodations. While the ALEKS Corporation has addressed their approach to upgrading their platform and code, still more work needs to be done to investigate solutions in this regard. As reported by the campuses in the pilots, they are not aware of students who could not complete the work in ALEKS during their pilots due to the need for accommodation.

Other challenges appear to hamper adoption on a larger scale — across a department or in all classes of a specific subject. Researchers noted that much communication about their research and findings and much more conversation will be needed at individual campuses to organize departments or programs around adopting ALEKS. It is one thing to conduct pilots and see positive results; it is another to use those results to plan a transformation into a program or practice with a much larger population. There are matters of academic policy, departmental programs, instructional integration and design, faculty freedom and organizational processes to consider and define in order to succeed at scale. And, technical integration into a university’s infrastructure is a costly endeavor. That, too, would need careful planning among numerous departments so that user access and data access for reporting and integrated views of student success are possible.

While each of the participating campuses reported there are ongoing discussions at their campuses regarding programmatic, policy and organizational concerns, discussions regarding institutional strategic planning were not reported.

RECOMMENDATIONS

While the campus groups formed recommendations for their own campus department programs and ongoing work, some of these recommendations may be applied more generally across UC campuses whose faculty consider using ALEKS — or any adaptive learning technology — alongside their academic courses in mathematics and science. These recommendations are

not comprehensive nor should they be interpreted to suggest efficacy systemwide. Rather, they are a result of the specific pilots and campus goals for those pilots that took place in a specific period of time. They are intended to inform ongoing investigations into the efficacy of adaptive learning in the context of campus academic programs intended to support student success and improve instruction.

Research and academics

RECOMMENDATION 1

Campuses should widely share their research and learnings about the use of ALEKS across the UC system. Some of the UC campuses have experience using ALEKS over a number of years in various models of implementation. The collected experiences of UC research faculty would help promote understanding of positive results, program designs and recommended practices. Campuses should explore various forums for sharing, through systemwide meetings, reports to appropriate administrative leadership or Academic Senate committees, use of the California Digital Library, and continued formal and informal collaborations.

RECOMMENDATION 2

Participating campuses should continue their work related to the positive findings in their research. By doing so, they will collect more student data; a larger data set will render more valid findings, and could, over time, reveal additional insights. Further, the continued work will help clarify program designs that may be considered for adoption within more academic disciplines and more broadly across UC, addressing some of the challenges universities face when considering implementing programs to scale.

RECOMMENDATION 3

Campuses should define clear academic goals regarding expected student academic achievement in specific disciplines addressed by systems such as ALEKS. The STEM disciplines appear to be best-poised to undertake this kind of academic planning and program design, which is not insignificant from either a content perspective or student- and faculty-support perspective. While systems such as ALEKS benefit from years of development and contain a great depth and breadth of content, academic departments and faculty are challenged with matching the learning outcomes and knowledge sequences across their courses (such as the mathematics sequence outlined by UC Santa Cruz) with the specific courses and knowledge sequences represented within the adaptive learning system.

Organizational enhancements

RECOMMENDATION 4

Campuses should identify all academic and administrative roles and points of contact required to support students and faculty/TAs who are utilizing adaptive learning solutions such as ALEKS. During the summer, when incoming students have not yet fully entered the system, communication across departments such as student affairs, academic advisement and the academic unit running the program needs to occur. The goals of the program should be clear, and the intended communications to students need to be known to the appropriate individuals whose role it is to work with incoming students. During the academic year, as well, similar communication and role clarity is highly recommended and may be beneficial to other student support groups.

RECOMMENDATION 5

Faculty and TAs should always be trained and prepared to use ALEKS and its reporting system so that appropriate instructional interventions or individual communications with students about their learning occurs in ways that support student learning and success. With this in place as part of any adaptive learning technology implementation, instructional methods can be improved alongside student results.

RECOMMENDATION 6

Campuses should investigate a coherent and cost-effective model that alleviates the burden of extra cost to students already burdened with high course materials fees (textbooks and the like). When ALEKS is used alongside an academic course, it presents an additional cost when a textbook or other core materials fees are expected. In summer, when ALEKS is used for placement, it is of concern to the campus departments that students would be charged for the system's use. Some view it as a department's responsibility if the implementation involves placement or research.

Technology and infrastructure

RECOMMENDATION 7

Campuses should ensure that all students participating in ALEKS have access to any accommodations they might need in order to successfully complete the work in ALEKS. This poses challenges in summer programs with incoming freshmen who have not yet identified as

needing accommodations. At present, the campuses are not aware of students who may choose not to participate or who don't complete ALEKS in the summer because of the need for accommodations. Clear and frequent communication with students as well as monitoring their usage and progress within ALEKS may help identify students with needs, but it does not alleviate the impact of the problem. The providers of the ALEKS system will need to look to evolving technologies to address the accessibility issue.

RECOMMENDATION 8

Campuses should begin to have broader and focused discussions about student learning data and academic uses of that data across the institution, and include infrastructure planning in meaningful ways. Some universities report these discussions to be strategically important and critical to achieving academic goals for the institution, including the successful education of its student body. Student Affairs, Academic Advisement, Academic Research, Teaching and Learning and Diversity and Engagement have varying interest in and need for such data. Students, too, would benefit from access to this data, and in coherent ways. The challenges of integrating systems and access to data for effective use by administration, faculty and students remain a large concern for many university systems.

CONCLUSION

The Adaptive Learning Technology Pilot study at UC using the ALEKS system in mathematics and chemistry suggests that the system can be helpful to certain student populations when specific program objectives are defined and organizational considerations are addressed before the system is implemented. Students benefit when the success targets are clearly stated and when they are motivated to succeed and persist in ALEKS until their targets are met.

At the same time the pilot study revealed challenges related to more widespread implementation of ALEKS, including cost to students, accessibility of the content to students with disabilities, and communication with incoming students, particularly during the summer, viewed as an important time to prepare students and improve their chances for success during freshman year. From an institutional perspective, matters of academic policy, program integration, faculty freedom, cost and organizational processes represent significant challenges to integrating such tools across a department.

Each campus research team believes that ALEKS had a positive impact in the context it was applied at their campus, but ALEKS is not a panacea for student success. The researchers will

share their results widely and continue investigations into using adaptive learning tools such as ALEKS to support student learning and success.

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