Increasing student success in General Chemistry (CHEM 211, 212, 213) with coordinated implementation of online homework (ALEKS)

Miriam Buschhaus, Department of Chemistry and Biochemistry, CSU Bakersfield
mbuschhaus@csub.edu
www.csub.edu/chemistry

Project Abstract
The online homework system ALEKS is employed to increase student success in General Chemistry, in response to increased class sizes and traditionally high D/F/WU/W rates. An efficient and effective implementation of online homework must be created using assessment feedback and policy refinement to obtain maximum student learning. Our coordinated ALEKS implementation across all course sections includes common expectations for each weekly due date, with topic counts matched to typical student learning curves; common homework policies; and common homework grade weighting. Students are supported by a TA-staffed ALEKS computer lab Monday through Friday. Initial assessment results are promising and will be reported in due time.

Motivation for coordinated ALEKS implementation
Regular practice and problem-solving is absolutely necessary to master chemistry concepts. Online homework is also becoming a necessity as class sizes increase. We desire to increase student success by making our implementation of online homework as effective as possible. Our chemistry department chose the ALEKS homework program, attracted by the adaptive and assessment features. Our redesign goal is to create a coordinated, consistent policy and practice for our online homework, optimized by measurable indicators of long-term student learning and resulting in consistent preparation for upper-level chemistry courses.

Redesign changes
Traditionally, chemistry homework consisted of paper-based textbook problems assigned and graded by the professor. As electronic resources became prevalent, static computer question sets developed, initially very similar to textbook questions and assigned to all students regardless of learning readiness. In recent years a number of advanced online homework programs have appeared, adaptive to individual students' current knowledge and learning readiness.
We selected **ALEKS** (Assessment and LEarning in Knowledge Spaces) for its strong adaptive emphasis and rigorous assessment capability. Our first year of implementation revealed the need to revise our policy and practice to optimize student success.

**Key aspects of our coordinated implementation include:**
- Concept progress (topic count) adapted to a typical student learning curve
- Coordinated weekly assessment and weekly due dates
- Open choice among ready-to-learn concepts
- Support with TA-staffed computer lab available Monday through Friday
- First and second week policies for early identification of struggling students
- Consistent grading structure rewarding learning progress
- Coordinating faculty member responsible for programing ALEKS sections and due dates
- Consistent implementation and strategic review for knowledge retention (CHEM 211 to CHEM 212 to CHEM 213)

**Student learning and success in the redesigned model**

Our coordinated implementation is designed to increase student success by individualizing the student experience using the adaptive ALEKS program, without sacrificing rigorous assessment to ensure long-term learning. Weekly due dates and progress goals keep students engaged and practicing regularly. Consistent policy implementation over multiple courses and sections prepares students equally and effectively for upper-level classes. The ALEKS-designated computer lab and TAs provide support for both chemistry and ALEKS related questions, with flexibility for students to obtain help when they need it.

**Course background**

Our redesign project focuses on the general chemistry course sequence CHEM 211, CHEM 212 and CHEM 213 (Principles of General Chemistry I, II and III; three quarters). These are lower division major courses, and are often required as cognates in other science majors. The prerequisites are MATH 85 (or equivalent), and either a satisfactory score on the Chemistry Placement Test or CHEM 101. The CHEM 211–213 sequence is completed in order. Each course has a co-requisite laboratory as well.
Student background

The CHEM 211-212-213 courses serve a range of majors including our own chemistry and biochemistry majors (13%), biology majors (25%), engineering (17%), geology majors (8%), nursing (7%), PEAK (10%) and many others (20%).

Our student population has a large Hispanic component (40%) as well as other minority groups (23%). Many of our students are first-generation university students (42%), and require additional support and resources. As we assess our redesign project we plan to measure the success rate for these special groups relative to overall student success, hoping of course to see benefits rather than detriments for these typically higher-risk populations.

Students begin CHEM 211 with a range of abilities. The prerequisite CHEM 101 course attempts to prepare students with a basic chemical understanding. Some students challenge the 101 course with the CPT, and others are transfer students with some community college chemistry. Basic math competency is required, but we find students have a range of ability from strong to practically math-phobic.

In order to use ALEKS, students must be able to use computer technology (keyboard, mouse) and have access to internet either at home or by coming to the designated computer lab. The ALEKS program has a built-in calculator, periodic table, reference data, etc., and is designed to be independent of any specific textbook (although instructors can choose to use it with a variety of current textbooks). Our students’ experience shows a dedicated ALEKS notebook or binder for notes and calculations is an extremely helpful support to the online program.

Accessibility, Affordability, and Diversity

**Accessibility?** Students must be able to use a computer (view display, handle keyboard, use mouse/trackpad) to use the ALEKS program. Students with disabilities which prevent use of a computer would require alternate activities.

**Availability?** The ALEKS program requires internet access. Most students have 24-internet at home. The on-campus Monday-to-Friday designated ALEKS computer lab is available if students do not have home internet. Also, some students take advantage of local coffee shops with free Wi-Fi for their homework sessions! The constant availability of the ALEKS program works well with students’ schedules as they balance school, work and family responsibilities.

**Affordability?** A one-quarter ALEKS subscription costs $30 USD. The total cost for three quarters is $90 USD. Students with Financial Aid can purchase an ALEKS access code through the university bookstore. Instructors can offer a two-week code to
students which defers the payment deadline, for those times when Financial Aid is delayed.

**Diversity?** Most students are fully computer literate, regardless of background. For students with less computer experience, the ALEKS program has tutorials and the designated computer lab has TAs able to answer both chemistry and computer questions. The TAs are drawn from upper-level chemistry students who reflect the diversity of backgrounds already present in the chemistry department, and who can serve as role-models to the lower-division students.

Our university serves a large Hispanic population and large numbers of first-generation students. Because ALEKS adapts to each individual student’s learning profile, these students are served much better than with traditional homework models. We hope to explore and measure the impact of ALEKS on these higher-risk student populations as part of our redesign project.

**The structure of ALEKS (Assessment and LEarning in Knowledge Spaces)**

ALEKS is an **adaptive online learning system** which individually customizes the time-on-task learning experience for each student using periodic assessment and active problem-solving. The initial log-in process includes a tutorial on the mechanics of system use. Each student then receives an initial assessment which determines the current knowledge level (consisting of the concepts a student already knows) and determines which concepts are suitable to learn next based on the empirically determined knowledge space map. The student and the professor are presented with the individualized ALEKS “pie” showing both known and yet-to-learn concepts (an example is shown in the image above). The concepts included in a particular course can be selected by the professor from over 400 general chemistry topics available. Each concept is contained within larger categories as shown in the “pie”. Each topic area contains a variety of questions, some conceptual, some graphical, others calculation-focused (algorithmic), but never multiple choice. Students practice each concept at least three times, or more if initial attempts are wrong. The completed concepts are added to the known portion of the “pie”. We call this the “homework mode”. Periodic assessments revise the real-time picture of the student’s knowledge level, expanding the “pie” where concepts are truly learned and remembered, and shrinking it where concepts are forgotten or understanding is weak.

The first key feature attracting our attention to ALEKS is its emphasis on **adaptation** to individual student’s learning needs and levels. This gives us the flexibility we need to engage the entire range of student abilities present at the beginning of CHEM 211 and bring the typical student to a sufficiently high level by the end of CHEM 213. Each student is given immediate feedback on each question answered in the homework mode, and specific explanations of each question are available with a mouse-click. The
continuous adaptation to changing knowledge levels through the entire course is crucial. The strengths and weaknesses of each student are unique, and ALEKS responds to both aspects.

The second key feature is the rigorous assessment capability. The regular assessments pin-point weak areas and require students to practice again by returning the concept(s) to the unlearned portion of the "pie". We have found this process significantly hinders the classic short-term learn-and-forget habit, and promotes long term learning. (There is, of course, a certain amount of student grumbling about having to “repeat” concepts they have “already learned”. However, when I ask whether they would prefer to discover they are still weak in an area in homework or on an exam, they generally look thoughtful and admit they see the value of it.)

The assessments also give the professor clear indications of a student’s knowledge and retention. A student with good retention will lose very few concepts each assessment cycle and a strong student may even move forward. A weak student with poor retention will fall back in assessment, indicating a need for additional support. However, even the weak students make progress from one assessment to the next; like the waves of an incoming tide, each assessment is “a little higher than the last”.

Our implementation strategy.

Our initial attempts to use the ALEKS program varied between professors, and, although promising, were not as successful as we desired. We have therefore systematically varied our implementation, improving on successful strategies and coordinating our efforts across multiple courses, sections and instructors. This section sketches the main aspects of our adaptation and current redesign position.

**Concept selection.** We selected the concepts appropriate to the topics and expectations of each course. From the total 400+ concepts available, we chose 180 for CHEM 211, 180 for CHEM 212, and 220 for CHEM 213. We included strategic review of key concepts in our selection, to reinforce and refresh the most important chemistry topics over the duration of the course sequence. Based on student feedback and our own observations, a few concepts had to be exchanged for others in the same area, usually because of undue difficulty or the presence of advanced concepts not covered in the lecture.

**Completion due dates, intermediate and final goals.** Initially we tried a single completion deadline at the end of the course, but students procrastinated to the last week and all learning benefit was lost. Three goals spaced evenly through the quarter gave similar results. Weekly goals have proved successful, promoting regular practice and helping students accomplish the entire "pie" by the end of the course. The weekly goals give incentive to time-on-task, which we believe results in increased learning.
The weekly due date was initially set for Friday midnight, but student feedback via in-class questionnaires indicated Sunday midnight would be preferred by most students. We therefore made the change to Sunday night. Follow-up surveys suggest students continue to prefer this day of the week. We still observe a certain amount of procrastination, as many students will work the most in the two or three days before the goal is due, but other students work through the entire week. The ALEKS program allows instructors to track minutes per day for each student and also to view overall website hits per day over the entire quarter. Setting the deadline at midnight makes tracking by date easier for professors.

**Assessment frequency.** Each assessment adjusts the knowledge level represented by the “pie”. The ALEKS program default is to give an assessment either every 5 hours of working time or after 20 concepts learned. In this mode the assessments seem to appear ‘randomly’ to the students. And since the most time is spent and the most concepts learned near a deadline, inevitably the assessment would appear just when a student least desired the interruption. Some students skipped the assessment questions to ‘save time’ but ALEKS interprets this as complete loss of knowledge and resets the “pie” to practically zero, wiping out all progress.

We realized we needed more control over the assessment process and so introduced regular scheduled assessments. Students are required to complete one assessment per week before working on the “pie” in homework mode. Each assessment is available Monday morning (immediately after midnight) until the Sunday midnight deadline, and must be started with the first log-in of the week. Thus students cannot avoid taking the assessment, but they can choose if the first log-in will be Monday, Tuesday, Wednesday ... or even Sunday afternoon. Students appreciate the ability to fit the assessment into their schedules and the knowledge it will not appear again as they work towards meeting the goal. Necessary as assessments are for learning-enforcement in ALEKS, they are not appropriate measures for a grade because they test both learned concepts (knowledge retention) and ready-to-learn concepts (knowledge readiness).

**Concept distribution per goal.** Each weekly goal must be linked to some measurable amount of progress in order to assign a fair grade. We analyzed our existing student data, graphing concepts learned versus time spent, and discovered a distinct learning curve which showed students learned more concepts at the beginning of the quarter and slowed down toward the end. (This may be linked to concept difficulty.) We therefore distributed our chosen topics according to the student learning curve, assigning higher concept completion counts in the first couple weeks and tapering off towards the end of the quarter. As before, we sought student feedback as well as analyzing the resulting data. Students generally liked finishing the easier concepts early (some of them are foundational math review), but they requested a leveled-off, more equal distribution in
the latter half of the quarter. The concept counts were refined for the current redesign in light of the feedback.

I also verified the concepts and concept counts against the typical lecture material; I wanted to be sure students were not required to finish concepts to reach a goal before learning that topic in lecture. The match is almost perfect. Of course, not every student will do only concepts related to lecture; some "explore ahead" either in interest or seeking an "easy" concept to finish a week’s goal. However, the match to lecture is viable, and to assist students I created an ALEKS Guidebook document which correlates the ALEKS concepts to material covered in lecture.

Open “pie” versus closed “pie”. ALEKS offers instructors a choice between making all concepts available (subject only to a student’s readiness to learn them) and releasing certain concepts at certain dates. We call these two possibilities an open “pie” and a closed “pie”, respectively. Initially we tried a closed “pie” model because we thought timed-release coordinated with the lecture might work well. But we found the opposite. The closed “pie” model resulted in struggling students, especially for weak students who fell behind and could not catch-up. We therefore moved to an open “pie” model, and provided optional correlation through the ALEKS Guidebook documents. Preliminary results are promising. In general, students do not struggle and fall behind as badly in the open “pie” model. The availability of the Guidebook must be promoted to students; otherwise they ignore it even though it is posted on the course home page in Blackboard (our learning management system).

Grade structure. From a variety of grade structures created by each individual professor we have moved towards a coordinated policy. One variation we tested had an equal weight on each goal (whether three per quarter or weekly). This model negatively impacted students who missed one goal, even for legitimate reasons such as illness or an athletic event. Also, many students decided to partially complete or skip the last goal, accepting the grade penalty to avoid the ‘hard’ concepts at the end and compromising their own learning performance. We are currently using a 60%/40% model. Each of nine weekly goals contributes 6.7% for a total of 60%, and the final completion of the “pie” contributes 40% to the overall homework grade. The weight on the final “pie” completion compensates for a missed week (if a student catches up) and gives the necessary incentive to keep students on task at the quarter’s end.

We have found by experience the homework component represented by ALEKS must be given sufficient weight in the overall course grade. Our model has varied as we transitioned through changes in the course structure. In general, we observe a 25% homework contribution is appropriate when lab is part of the overall course grade. Homework percentages of 35% - 40% seem to be effective when the lab is separate from the lecture; we are still analyzing these numbers in light of recent course changes in our own program.
We assign our ALEKS grades based on completion of the required number of concepts, thus encouraging student effort and time-on-task. Failure to finish the weekly assessment means a zero for the week. After the assessment, concepts in the "pie" count towards the weekly score. Students can reach the goal (100% for the week) or come close to it (for example, three-quarters of the way scores 75% for the week). Even weak students can obtain a good homework score if they are willing to put in the extra time they need to complete the concepts. We also find the homework grade compensates somewhat for the difficulty of the chemistry exams, encouraging students to keep trying even after a discouraging exam experience. Of course, the incentive to do more homework results in learning that ought to carry over to the exams as well.

Incentives. We are experimenting with a variety of additional incentives to reward effort in ALEKS. For example, in CHEM 213 students can earn a small exam bonus for each ALEKS goal they complete to 100%. Students do respond to the incentives. We are still analyzing the effect on actual learning.

We consistently observe in all classes that beginning ALEKS in the first week of classes (rather than procrastinating) leads to greater success. We introduced an incentive to encourage early engagement with the ALEKS program in the form of a bonus for completing the initial assessment by a certain date. This policy still leaves time for students who add to the course in the second week to meet the first graded goal.

First and second week policies and early identification of weak students. Analysis of ALEKS data for a quarter showed some interesting patterns. Students with a zero in either of the first two weekly goals or a low score in both goals were significantly more likely to receive a D, F, W or WU grade in the course. I am very interested in these patterns as an 'early warning' system to identify students who would benefit from intervention and additional support. Our department is testing a set of policies that encourage constructive behavior, specifically stating in the syllabus that students must complete the first two goals or risk removal from the course. This policy helped initially, but some students now complete the minimum to remain in the course for the first two or three weeks and then lapse into failing habits thereafter. Much more analysis and development is need in this area.

Coordination between faculty. The success of our promising redesign model depends on faculty coordination. Faculty must be willing to share experience and data to arrive at appropriate policies. Coordination also benefits the student experience in many ways. Common, clear expectations between the three courses make the overall general chemistry experience smoother. Learning continues efficiently from quarter to quarter. Common expectations between sections, even with different professors, prevents instructor-shopping for the easiest grader. (Of course, many students will still choose a professor based on a match between lecture style and learning style.) It also promotes
equal worth to the course grades; the A, B and C grades have consistent meaning across the different sections, and the measure of readiness for the next course is more reliable.

Coordination also means one faculty member can become the local ALEKS expert. The concepts can be selected in a master course template, which can be copied each time the course is taught. The dates of each weekly goal need to be entered into the ALEKS program at the beginning of each course. Duplicate sections are then created and designated to the appropriate professors. Sometimes students accidentally enroll in the wrong sections, making at least one faculty member with universal administrative access necessary. This person can easily transfer students between sections with a simple drag-and-drop procedure. But this person can also modify any aspect of the master templates and the individual sections, and therefore must be trustworthy and careful.

**TA-staffed, ALEKS-designated computer lab.** The use of an ALEKS-designated computer lab staffed with TAs (upper level chemistry students) is relatively new in our implementation efforts, and would not be possible without the support provided by this promising redesign project. The computer lab will be available Monday through Friday with almost constant TA availability. We think this will be a key tool to support students, especially as professors are not available to answer questions all the time.

Our initial feedback shows two types of students use the ALEKS computer lab. One group will drop in only when necessary to ask about a particular concept they are struggling to understand. Another group comes regularly each week, using the computers to do their ALEKS homework and interacting with the TA when they need help. Some popular TAs develop a ‘following’ during their hour. These TAs are providing chemistry and ALEKS program support, and they are also serving as role models to the lower-division students.

As we analyze the effectiveness of the designated computer lab, we will be trying to identify the best usage patterns, and leverage them into even greater effectiveness if possible. Can we help and support students more efficiently? Are some hours under-attended and others heavily attended, suggesting redistribution of TA availability? Can we use the computer lab to help struggling students who have been identified in the first two goals, for example by making attendance mandatory until the students catch up?

**Assessing the effectiveness of our redesign project**

We will judge the effectiveness of our ALEKS strategies by comparing student performance in ALEKS to overall course grade, to exam grades, and most importantly to the ACS General Chemistry exam grades. The ACS General Chemistry exam is a cumulative, nationally-standardized exam prepared by the American Chemical Society. We administer the ACS exam as the final exam in CHEM 213, giving us a benchmark to
compare our students to national norms, and to track our progress from year to year. We anticipate better ACS exam results if ALEKS is effectively increasing student learning and long-term retention of concepts from CHEM 211 to CHEM 212 to CHEM 213.

We will also monitor the D, F, WU and W rates for the classes, hoping of course to see a reduction in these repeatable grades as ALEKS helps students become more successful. However, sharply increasing class sizes and restructuring of our program to divide lecture and lab components into separate courses may also impact the pass rates, so interpretation of this data may be more difficult.

As mentioned before, we will also measure the success rate of our minority and first-generation student populations relative to overall student success. We anticipate the adaptive ability of ALEKS will help these typically higher-risk populations.

**About our team**

I (Miriam Buschhaus) teach in the General Chemistry course sequence, with Sam Hudson, Hanoz Santoke, Gerd Rabe, Tiffany Pawluk, Dennis Harvey and occasionally David Saiki, at the California State University, Bakersfield (CSUB). Our chemistry department began using online homework about four years ago. More recently we began a coordinated effort to analyze and improve our implementation to maximize student learning. My role includes faculty coordination, ALEKS programming, and document preparation. David Saiki and Andreas Gebauer will be very involved in data analysis and results. Two aspects I hope focus on this academic year are the impact of the TA-staffed computer lab and the effect of adapting to a separated lecture and lab situation compared to the previous combined lecture and lab course.