Committee on Educational Policy
Math Placement and Instruction at UC Santa Cruz

For the last several years, the mathematics placement system at UC Santa Cruz has used ALEKS (Assessment and LEarning in Knowledge Spaces).[1] With the establishment of the Department of Applied Mathematics, there are now two departments in two divisions whose courses are directly affected by the placement system: Applied Mathematics in the Baskin School of Engineering and Mathematics in the Division of Physical and Biological Sciences. In addition, given the foundational nature of mathematics instruction, a broad range of departments are indirectly affected by the placement system.

As with the Entry Level Writing Requirement, supervision of the mathematics placement system is assigned to Academic Senate committees. In the Santa Cruz Division, this function has been performed by the Committee on Preparatory Education. With this committee being vacant for the last two years, at the request of the Committee on Committees, the responsibility devolved to the Committee on Educational Policy (CEP) because of its general authority over undergraduate curricula.[2]

Because of the costs associated with running the mathematics placement system, the Administration also has an interest in this issue.

CEP has studied the mathematics placement system over the last two years, and is proposing the following steps. This proposal is guided by the data analysis in the report from Institutional Research and Policy Studies (IRAPS). We have also included one item about mathematics instruction.

After consultation with stakeholders at the start of the 2020-21 academic year, we hope that the committee is able to make decisions by the end of Fall 2020, so that there is time to implement them for the class entering UCSC in Fall 2021.

1. The number of attempts at the ALEKS placement test should be reduced to 2, and the duration of each attempt should be reduced.

The main feature of ALEKS that distinguishes it from other placement tests is that it identifies areas of weakness in a student's preparation, gives them an opportunity to brush up these areas, and enables them to place higher as a result of improved preparation. At present, UCSC allows students five attempts at the placement test. As the number of attempts is increased, there is a danger of random fluctuations occurring from one attempt to the next, with students quitting when they are "ahead".

We believe that the number of attempts at the test should be limited to two: the first attempt, further preparation, and a retest for the final placement. Very few students attempt the test more than twice (< 5% according to the 2015 IRAPS report), so the impact on students will be minimal. In fact, this change may cause students to study the ALEKS modules more seriously between their first and second (i.e. last) test. Paying more attention to the modules will benefit students.

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[1] One of the reasons to move away from the placement test that was originally used (before the test that preceded ALEKS) was that it was too expensive. This is no longer a factor, since that test is online and would not cost the campus anything.

[2] This responsibility will be formally transferred to CEP from September 1, 2020.

UCSC also allows a 48-hour time limit for each attempt of the test. It is desirable that the test should not be measuring simply how fast a student can answer questions. However, success in a course — which is the goal of a placement test — is related to fluency with the background material, not just knowledge thereof. Considering the length of the placement test — 45 questions — we believe that a 3-4 hour time limit (i.e., 4-5 minutes per problem) should be sufficient. A student can start their test at any time that is convenient to them, when they have a free time window and a good Internet connection.

2. Students should have the option to place into MATH 3, and perhaps MATH 11A and 19A, based on SAT scores.

The IRAPS analysis shows that Mathematics SAT scores are the best predictor of success in MATH 3. UCSC cannot exclusively rely on SAT scores, especially as they are being de-emphasized in UC admissions. However, based on the IRAPS analysis, we believe that students who do have SAT scores, and have scores above a certain threshold, should be allowed to place directly into MATH 3. The appropriate threshold should be determined based on data analysis, as the score above which students are very likely to succeed in MATH 3. We emphasize that students who are below the threshold may also have a significant chance of succeeding in MATH 3. They will be able to use ALEKS to place into the course. Information provided to students should not portray this as "challenging" their SAT-based placement.

The IRAPS analysis did not reach a similar conclusion about SAT scores as being the main predictor of success in MATH 11A and 19A. This means that a similar threshold SAT score for these courses is likely to be high, with many students who should take these courses being below threshold. Nevertheless, since we are only proposing to use SAT scores as an *alternative* to ALEKS rather than the sole placement tool, it is worth verifying — through a similar data analysis as for MATH 3 — whether threshold SAT scores can also be prescribed for these courses. Students above the thresholds for MATH 11A and MATH 19A would automatically place into the respective courses, and other students would go through ALEKS. Eliminating the unnecessary use of ALEKS would reduce burdens for students.

3. The appropriate cutoff ALEKS scores for MATH 3, MATH 11A, MATH 19A and MATH 20A should be determined in Fall 2020.

The cutoff scores in ALEKS that allow a student to place into various introductory mathematics courses are not determined by ALEKS, and have not been analyzed by IRAPS. They should be examined through an analysis **conducted jointly by the Applied Mathematics and Mathematics Departments**. (Although the introductory courses offered by the two departments are not identical, they are often functionally equivalent, and it is desirable to retain this feature.) The departments should design a low-stakes first assignment in each introductory course to test the key concepts that students should have acquired before taking the course. A rubric-based analysis for each course would reveal if there are specific areas in which students are deficient, so that these areas can be emphasized in the course. It would also show if students are below expectations in several different areas, and how this is correlated with ALEKS scores. This would enable the appropriate cutoff ALEKS score for each course to be determined.

While we do not know what these cutoffs will be, as indicated in Table 1 below, the increase in the percentage of students placing out of precalculus courses after ALEKS was adopted has been

accompanied by an increase in the percentage of students failing calculus courses at UCSC, which would suggest that the cutoffs should be higher than they are.

Table 1: Comparison of enrollments in MATH 2 and MATH 11A between 2014-15 and 2018-19

	MATH 2 enrollments	MATH 11A enrollments
2014-2015	766 students (26% failure rates)	1117 students (18% failure rates)
2018-2019	129 students (13% failure rates)	908 students (25% failure rates)

Any change in cutoff has to be coupled with effective instruction in precalculus courses. For students, the success in precalculus courses directly influences the success in calculus courses. If the instruction in precalculus courses is not functioning properly, students who are not ready for calculus will not be brought up to speed by taking precalculus courses[3]. We turn to this point next.

4. UC Santa Cruz should emulate UC Riverside in improving instruction in introductory precalculus and calculus courses.

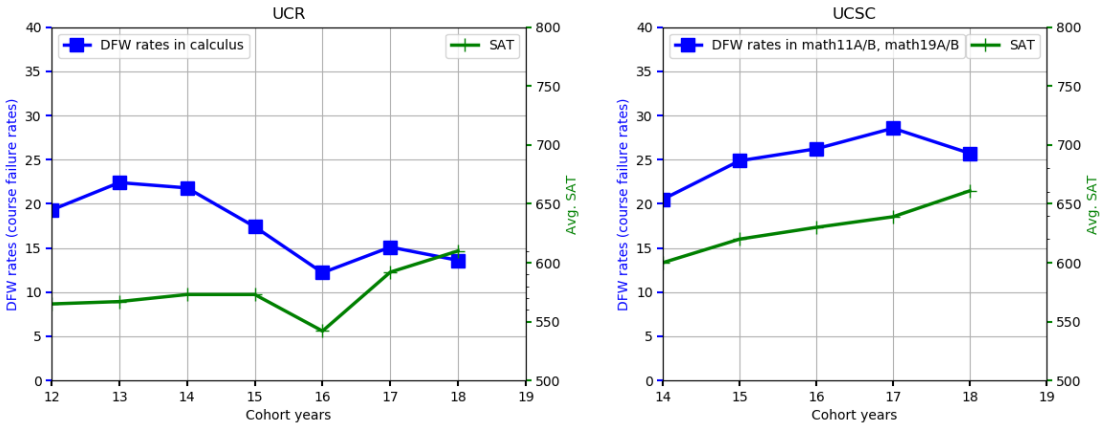

Figure 1: Failure rates and average SAT math scores at UC Riverside and UC Santa Cruz.

The results in Fig. 1show that the average SAT math scores (represented in green curves) of our students have been gradually increasing from 600 in 2014 cohort to 661 in 2018, and they are higher than the average scores of UCR students. Only in the recent two years have shown that the average scores were higher than 600 in the UCR data (610 in 2018; 619 in 2019). Nonetheless, it is discouraging to see that our students' DFW failure rates (displayed in blue curves) have been gradually increasing over the past years, and are indeed much higher than the UCR students' rates. In 2018, the UCR failure rate is 13.6%, while ours is 25.7%.

To investigate where the root source of this discrepancy between the two campuses, a CEP subcommittee reached out to Prof. Yat-Sun Poon, the Chair of the Mathematics department at UCR. According to the conversation with him, UCR has been able to improve their students' calculus performance by implementing two two-quarter long intense 5-credit[4] precalculus courses, MATH 4 and MATH 5 (our MATH 2 and MATH 3). The lecture class size is maintained between 150 and 200, accompanied by discussion sessions of 30 students. Instructors of the introductory courses at UCR

[3] However, if precalculus courses are not functioning effectively, this would not be an argument to place these students directly into calculus courses.

[4] At UCR, most courses are offered as 4-credit courses.

have been shifted from lecturers to ladder-rank faculty in the last few years. Prof. Poon believes that their calculus improvement has been available by the so-called "active learning system" in precalculus courses, by which students get enhanced interactive experience prior to taking calculus courses[5].

The calculus courses at UCR are offered in three different tracks, targeting students in physical sciences, biological sciences, and business. The maximum size of lectures is 120 and the maximum size of discussion sessions is 30, which are smaller than ours (lectures between 250 and 450, discussion sessions up to 40). They also collaborate proactively with Learning Center to provide a better support system. Prof. Poon shared his opinion on a math summer program, which would potentially bring the biggest improvement in overall students' performance in math courses at UCR.

Such changes (e.g., intensive training in precalculus courses in small class size prior to calculus courses) will, of course, require adequate resources. But we believe that if UC Riverside is willing and able to make such an investment in its students, there is no reason UC Santa Cruz cannot or should not do the same.

5. The effectiveness of ALEKS as a placement tool should be studied over the next two years. If it appears desirable, the campus should move to MDTP as the primary placement tool.

The effectiveness of ALEKS has been the subject of a statistical analysis by IRAPS, with a key conclusion being that the average grade obtained by students who place into a course after retesting differs from the average grade obtained by students who place into the course directly by a statistically insignificant amount. This, along with the dramatic reduction in the number of students taking precalculus courses, has been heralded as a success of the ALEKS system.

However, this conclusion from IRAPS has to be weighed against their conclusion that the best predictor of a student's performance in MATH 3 was their Mathematics SAT score, while the best predictor of a student's performance in MATH 11A and 19A was their initial ALEKS score. **Subsequent ALEKS scores were not the leading factor in predicting student performance in any of these courses.**

This is also seen in the graphical representation of the average grade in MATH 3 for various groups of students. In Fig. 2 and Table 2 below, students are grouped based on their initial and final ALEKS scores. Students in Group 1 and Group 2 were initially placed below MATH 3, however, students in Group 1 were replaced into MATH 3 while students in Group 2 were replaced above MATH 3. Students in Group 3 and Group 4 were originally placed at MATH 3. Group 3 students remained at MATH 3, while Group 4 students were placed above MATH 3.

If one compares Group 1 and Group 2 , or Group 3 and Group 4, one is comparing students with similar initial ALEKS scores and different final ALEKS scores. One can see that better final ALEKS scores do improve student performance. However, *both* Group 1 and Group 2are below Group 3 and Group 4, indicating that the initial ALEKS score is a stronger predictor of student performance than the final score. (If the converse had been true, and the final ALEKS score had been the dominant factor, we would have expected Group 1, Group 3, Group 2, and Group 4to be in order of increasing mean grade point.)

[5] Although a proper data analysis is not available, Prof. Poon stated that he feels that the impact of the changes at UC Riverside has been especially beneficial for disadvantaged groups.

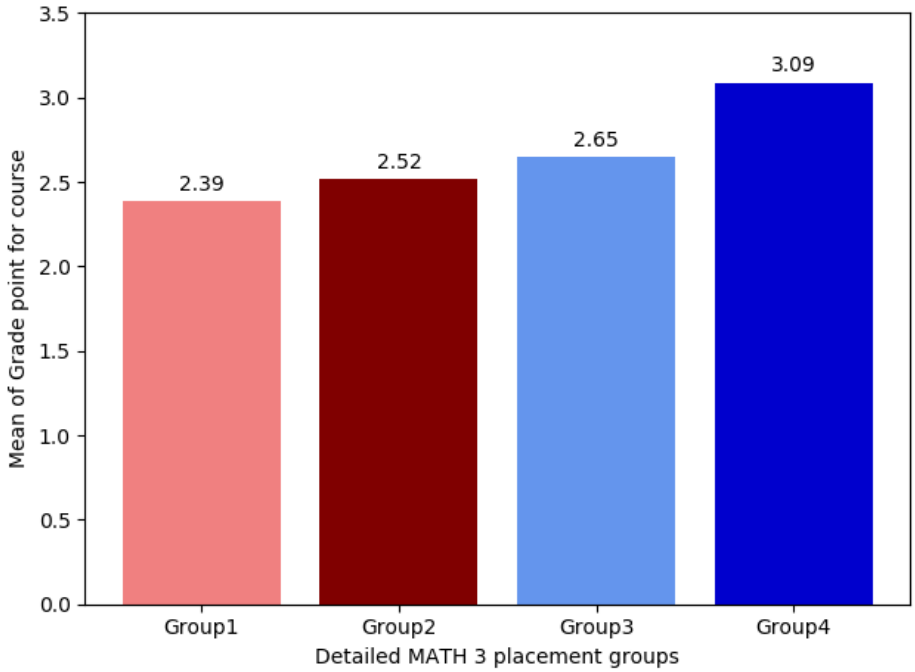

Figure 2: Mean of grade point distribution in MATH 3 among four different student groups. Each group is classified according to students' initial and final ALEKS scores, tabulated also in Table 2 below.

How do we reconcile these two seemingly contradictory conclusions from IRAPS? The table below explains the situation in detail:

Table 2: Results for Fall 2015 frosh enrolled in Math 3[6]

Groups	First ALEKS	Final ALEKS	n	Avg grade	Pass %	% B or above	% D, F, NP
Group 1	< Math 3	Math 3	89	2.39	68.5	40.5	19.1
Group 2	< Math 3	> Math 3	80	2.52	78.8	43.8	16.3
Group 3	Math 3	Math 3[7]	191	2.65	82.2	49.7	14.1
Group 4	Math 3	> Math 3	29	3.09	96.6	65.5	3.5
Group 5	> Math 3	> Math 3[4]	146	2.82	83.6	58.2	12.3

Apart from the fact that, as noted above with the graph, the primary clustering of the groups is by first ALEKS score rather than the final ALEKS score, we observe that there is not much difference at all

[6] Similar results are obtained for Math 11A.
[7] This includes students who did not take the test more than once.

between the various groups in the table. **Thus, ALEKS scores, whether initial or final, are not strongly correlated with the grade obtained in the course.** What difference there is can be better explained in terms of the initial ALEKS score, but at a 95% significance threshold, the differences between the first two groups and the third group is not significant.

The limited effectiveness of ALEKS does not mean that there is a *better* placement system. We note that UC Riverside has just transitioned from the MDTP Placement Test to ALEKS, and UC Merced is going in the opposite direction. We recommend that CEP work with its counterparts at these two campuses over the next two years to have an analysis done of the predictive power of the two placement tests, so that they can be compared and a decision made whether to retain ALEKS as the placement test. We also note that the MDTP placement test includes questions from calculus, which ALEKS does not, and seems therefore to be better suited to decide whether students are ready for MATH 11A or MATH 19A or MATH 20A.

Even if it turns out that MDTP — which is free — is a better placement test than ALEKS, it may be desirable to retain access to ALEKS at UCSC as a learning tool rather than for placement, especially for MATH 3, although the IRAPS study shows a *negative* correlation between the time spent in ALEKS PPL and a student's MATH 3 grade.

6. Proper advising of students is important

If a student starts the calculus level at a lower level than they need to, it can delay their progress in a STEM major. Students should not be told to start at a lower level because it is always better to start slowly. On the other hand, if students start at too high a level, it can demoralize them. Some students may self-assess themselves, and feel that they should take a class that is below the level for which they are eligible under ALEKS, which should be respected. We are pleased to see that the orientation materials being provided to students this year are informative and factual, enabling students to figure out what would be best for them.