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Examining the Effect of Changing College Algebra Curriculum on Underprepared Engineering Students

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Abstract

This Complete Evidence-based Practice paper will describe the effects of changing college algebra curriculum on underprepared first-year engineering students and their subsequent courses.

The University of Arkansas (UA) College of Engineering (CoE) has open enrollment, admitting any student who meets university criteria. Math placement is determined by standardized tests (ACT/SAT), an optional ALEKS exam, and recently high school GPA. Currently, 20% of incoming first-year engineering students start in College Algebra, two levels below the optimal entry point of Calculus I and are considered underprepared.

UA offers three tiers of College Algebra with 3, 4, or 5 weekly contact hours, corresponding to ACT math scores: below 19 (5-credit), 19–21 (4-credit), and 22–25 (3-credit). While all tiers share the same objectives, the 4- and 5-credit courses previously used ALEKS, while the 3-credit course used MyLab Math (MLM). In Fall 2023, the Department of Mathematics transitioned the 3-credit course to ALEKS to unify instruction.

MyLab Math by Pearson is a digital platform that enables instructors to create online assessments and assignments. It provides a variety of data to help instructors customize their courses and tailor the content to meet the needs of specific student groups. Exercises and problems in MyLab Math reflect the approach and learning style of a textbook, and regenerate problems algorithmically to give students unlimited opportunity for practice and mastery [1]. Similarly, ALEKS by McGraw Hill is another digital platform that allows instructors to build assessments and track student performance. However, the key difference between the two is that ALEKS uses an adaptive learning approach, requiring students to demonstrate mastery of a topic before progressing to the next. ALEKS uses machine learning rooted in Knowledge Space Theory to create and continually update a detailed map of each student's knowledge. It identifies, in real time, whether a student has mastered a specific topic and if they are ready to learn it. This approach is to keep students engaged, motivated and consistently working at the edge of their current knowledge without experiencing the frustration of overly challenging material or the boredom of concepts that are too simple [2].

The aim of this paper is to examine how the transition to ALEKS in Fall 2023 affected the progression of first-year engineering students that are required to take college algebra compared to the previous two years. We will compare the 3-credit hour College Algebra pass rates and the GPA's. Preliminary results show that engineering students passed the ALEKS course at a 4.39% higher rate than the previous year (up from 84.4%). While all students taking College Algebra passed at a 7.05% higher rate (up from 81.6%). We will also examine the pass rates and grade distributions of our students who continued to Precalculus and University Chemistry I, which require College Algebra as a prerequisite course, in the following spring semester to see if a

different algebra foundation affects them through these critical courses. Initial results show no significant difference in pass rates for students who completed the 3-credit hour College Algebra course, whether using MyLab Math or ALEKS, in their subsequent courses.

Introduction

College-level academic advising starts during new student orientation in the summer, where they are consulted on classes to take and resources available to them as they start on their academic journey. Currently, advisors consider a variety of factors for class placement when working in one-on-one meetings with the students including standardized tests, AP tests, prior college experience and self-efficacy. This process is particularly critical for students enrolling in mathematics courses. Currently, around 20% of incoming first-year engineering students (approximately 180/900 students) begin in a College Algebra course. This placement puts them two levels below the optimal starting point of Calculus I, categorizing them as underprepared. Advising these students can be particularly challenging, as they may also lack AP scores, prior college experience, or even, in some cases, standardized test scores.

In Summer 2023, advising for underprepared students was modified to include high school GPA as a placement factor. Students with a GPA below 3.7 continue to be placed in mathematics courses according to the guidelines in Table 1 [3]. Students with a GPA above 3.7 will be exempt from remediation and can enroll into the 3 day a week college algebra.

Table 1: College Algebra Math Placement

Course Title	Meeting Days	ACT Math Score	SAT Math Score	ALEKS Math Placement Score
College Algebra with 2 Hour Lab	5 meeting days	none	none	none
College Algebra with 1 Hour Lab	4 meeting days	19	510	30
College Algebra	3 meeting days	22	540	46

Table 1 shows how underprepared students are placed in their math courses based on incoming standardized test scores according to university policy [3].

As part of changes in advising, the Mathematics Department at the University of Arkansas updated the learning platform for the 3-credit-hour College Algebra course. Prior to Fall 2023, although all College Algebra courses shared common objectives, their instructional methods differed significantly. The 4- and 5-credit-hour courses used the ALEKS platform by McGraw Hill, while the 3-credit-hour course utilized MyLab Math (MLM) by Pearson. To streamline instruction and improve consistency across all College Algebra courses, the department adopted ALEKS for the 3-credit-hour course beginning in Fall 2023

Advising a student in their college curriculum based on their high school GPA caused some hesitation. A student's high school GPA is not a good predictor for academic performance in college, unless their GPA is above a 4.0 [4]. There are many reasons for inconsistent high school

GPAs, thus making them seem incomparable. They are based on criteria developed by individual teachers, often within the context of varying curricula. These grades are assigned based on a diverse set of tasks measured over time, reflecting not only academic knowledge and skills but also behaviors, effort, and teacher judgment. Factors such as differences in course difficulty, curriculum standards, and grading practices further contribute to the variability, making direct comparisons challenging [5].

In this paper we will be considering students enrolled in the 3-credit hour College Algebra course in Fall 2021, Fall 2022 and Fall 2023. We follow up with students who continue to Precalculus and/or University Chemistry I in the subsequent Spring semester. College Algebra served 2799, 3510, and 3162 students in the fall semester respectively with the 3-credit hour College Algebra course serving 1194, 1432, and 1608 students each fall semester, respectively. After analyzing the total 3-credit hour College Algebra population, we will narrow the scope of our focus and conduct a similar analysis specifically on our first-year engineering students who are enrolled in the 3-credit hour College Algebra (underprepared). Currently, roughly 10% of incoming first-year engineering students (approximately 90 students of 900) begin in the 3-hour College Algebra courses.

College Algebra serves as a prerequisite for both Precalculus and University Chemistry I, which are required courses in all our engineering majors and many other STEM majors on campus. Because these subjects build directly on the mathematical skills developed in College Algebra, they provide a meaningful way to assess the impact of any changes made to the course. By examining student success in these subsequent courses, we can determine the impact of the modifications to College Algebra.

There are 8.6% of the 3-credit hour College Algebra students enrolled in the Precalculus in the following Spring semester. During this time, Precalculus uses Pathways to Calculus online learning platform developed by Marilyn Carlson [6]. Precalculus' Pathways to Calculus online platform is a research-based curriculum designed to strengthen students' foundational mathematical understanding, particularly in algebra and precalculus, to better prepare them for success in calculus. It incorporates lessons to complete inside of the classroom with an online platform to support the learning presented in the classroom. The in-class learning incorporates group discussions, inquiry-based activities, and problem-solving tasks to engage students and promote persistence in learning, while in the online platform presents multiple representations and conceptual foundations to strengthen student's reasoning skills. Since this platform differs from both ALEKS and MyLab Math, students do not gain any advantage from engaging with those systems beforehand.

Approximately 14.8% of students from the 3-credit hour College Algebra course enrolled in University Chemistry I the following spring. University Chemistry I utilizes MyLab and Mastering Chemistry, a Pearson product. Mastering Chemistry has assigned modules that are similar to the mathematics courses but also includes problems to actively engage in understanding chemistry concepts and building problem-solving skills for success in their course [6]. Although students in the Fall 2021 and Fall 2022 College Algebra courses also used a Pearson platform, the structure, content, and implementation of the two courses differed

significantly. These differences prevented students from gaining any meaningful advantage from prior exposure to the similar platform.

Research Questions

1. How did the transition to ALEKS in Fall 2023 affect the progression of students that are required to take the university's 3-credit hour algebra course compared to the previous two years?
2. How did the transition to ALEKS in Fall 2023 affect the progression of first-year engineering students that are required to take university's 3-credit hour college algebra compared to the previous two years?

Methods

The University of Arkansas collects and retains students' grades, for courses they are enrolled in along with admissions data (high school GPA, ACT/SAT score). The data analyzed in this study were limited to the students enrolled into 3-credit hour College Algebra in Fall 2021, Fall 2022, and Fall 2023. This included 1194 students who used MLM in Fall 2021, 1432 students who used MLM in Fall 2022, and 1608 students who used ALEKS in Fall 2023.

To assess the impact of transitioning to ALEKS, we analyzed pass/fail rates across different datasets (Fall 2021, Fall 2022, and Fall 2023). A passing grade was defined as earning an A, B, or C, while a failing grade included D, F, or W. Additionally, we examined pass rates and grade distributions of students who advanced to Precalculus and University Chemistry I in the following Spring semester. This analysis helped determine whether differences in their algebra online platform influenced performance in these key courses. Since College Algebra is a prerequisite for both, tracking student success in these subjects provides insight into how changes to the 3-credit hour College Algebra course affect long-term academic outcomes.

A Chi-Square Test for Independence was conducted to determine whether there was a significant difference in pass rates between groups. This test compares expected and observed distributions based on student enrollment by semester (row totals) and pass/fail outcomes (column totals). Following this, a post-hoc analysis using adjusted residuals was performed to evaluate differences in pass rates between the groups.

A chi-square test is appropriate for comparing pass rates in the courses across semesters because the data consists of cross-categorical variables (semester and pass/fail status) [8]. This test determines whether there is a significant association between semester enrollment and student success. Because the chi-square test is an all-encompassing test, post hoc procedures are needed to compare individual conditions [8]. If the chi-square test reveals a significant difference, a post-hoc analysis is needed to identify which specific semesters differ in pass rates. By analyzing adjusted residuals, conducting pairwise comparisons with a Bonferroni correction, this pinpoints whether changes in the online platform had a meaningful impact on students learning [8].

Finally, we focused our analysis on first-year engineering students enrolled in the 3-credit hour College Algebra courses during Fall 2021, Fall 2022, and Fall 2023. Specifically, this included 76 students using MLM in Fall 2021, 96 students using MLM in Fall 2022, and 89 students using

ALEKS in Fall 2023. As described earlier, our statistical analysis involved a Chi-Square Test for Independence, followed by a post-hoc analysis. This analysis examined the pass/fail rates of students in College Algebra during the fall semester and their subsequent performance in Precalculus and/or University Chemistry I in the following spring semester. For our first-year engineering students, we also took into consideration the first-year retention rates and average ACT scores.

Results

Full 3-credit hour College Algebra Population

The first analysis includes all the students enrolled in the 3-credit hour College Algebra courses. This includes 1194 students who used MLM in Fall 2021, 1432 students who used MLM in Fall 2022, and 1608 students who used ALEKS in Fall 2023.

The first effect examined is whether the change from MLM to ALEKS influenced grades of all students enrolled in 3-credit hour College Algebra. For this analysis, D, F, and W are considered negative outcomes, as they would prevent students from advancing to the next mathematics course. Students who do not need additional math courses technically pass with a D. However, for our purposes, passing includes grades A, B, and C.

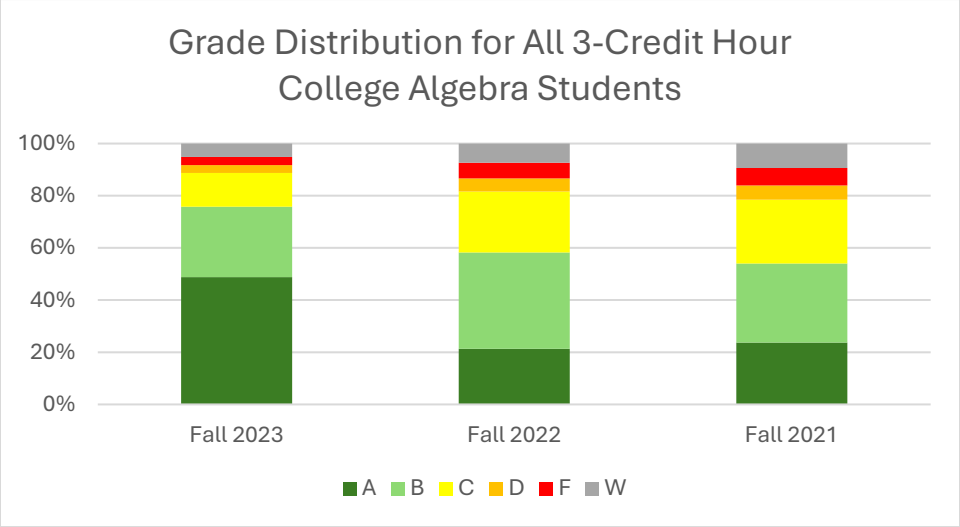

Figure 1. Grade distribution by year for all students in 3-Credit Hour College Algebra

Immediately visible is that the percentage of A students more than doubled from 22% in the previous years to 49% in 2023. While this is encouraging, it could also suggest that the new system may be more lenient for high-achieving students. To gain a fuller understanding, the pass rates of subsequent that rely on this content (Precalculus and University Chemistry I) were also analyzed.

Table 2: Pass rates for 3-credit hour College Algebra and Precalculus and Chemistry I after completing 3-credit hour College Algebra. *indicates a significant difference from the mean.

Pass Rates (All students)	3-credit hour College Algebra (3CA)	Precalculus after 3CA	Chemistry I after 3CA
23-24	88.7% *	83.7%	63.5%
22-23	81.6%	79.7%	63.7%
21-22	78.5% *	92.2% *	60.6%
3-yr total	83.4%	84.7%	62.7%
Total n	4234	366	627
Chi-Squared test (p)	$5.1x10^{-13}$	0.032	0.786

A Chi-squared test for independence showed differences in pass rates between the years for 3-credit hour College Algebra and Precalculus, but not University Chemistry I. A post-hoc analysis showed that College Algebra pass rates were below average in Fall 2021 and rose above average in Fall 2023. This is a desired trend which we hope continues. In contrast, the pass rates for Precalculus were above the average in 2021, possibly a symptom of post-Covid sympathy, as no F's awarded in that semester. The consistency of Chemistry grades among this population is disappointing as we had hoped a better foundation in algebra seen through improved college algebra grades would have led to increased chemistry success.

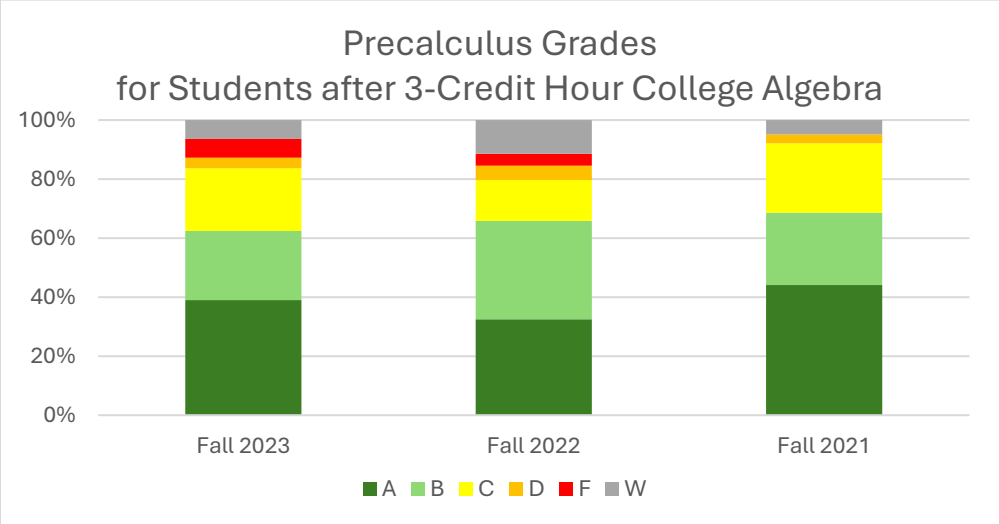

Figure 2. Grade distribution by year for all students in Precalculus after 3-Credit Hour College Algebra.

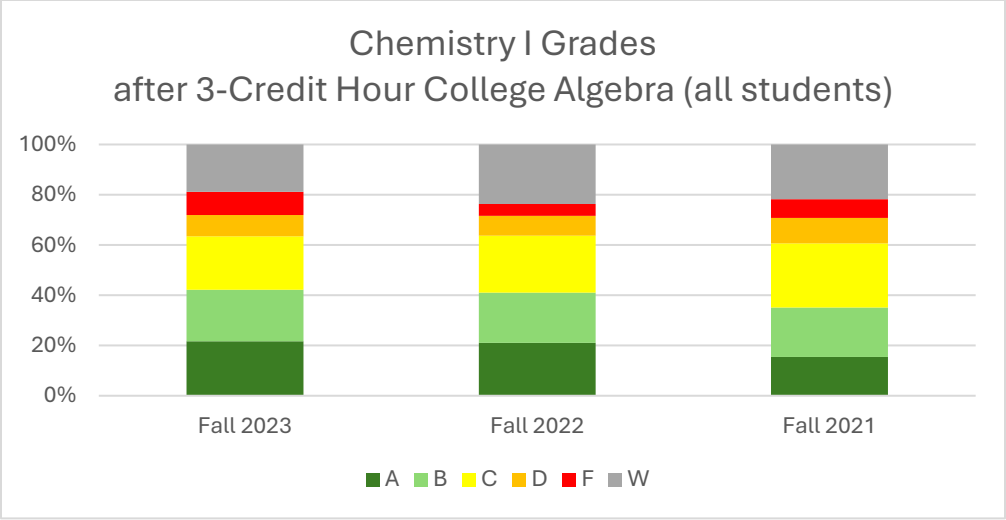

Figure 3. Chemistry I grade distribution by year after 3-credit College Algebra

The grade distributions for Precalculus and University Chemistry I have remained stable over the period for those who took the 3-credit hour College Algebra course. For further analysis, we examine just those within the college of engineering.

Engineering College Algebra Population

Our second question was "how did the transition to ALEKS in Fall 2023 affect the progression of first-year engineering students that are required to take university's 3-credit hour college algebra compared to the previous two years?"

We first analyzed the grade distribution for 3-credit hour College Algebra. Mirroring the general population of college algebra students, we saw that first-year engineering students who received an A in college algebra increased from 20% to 43%.

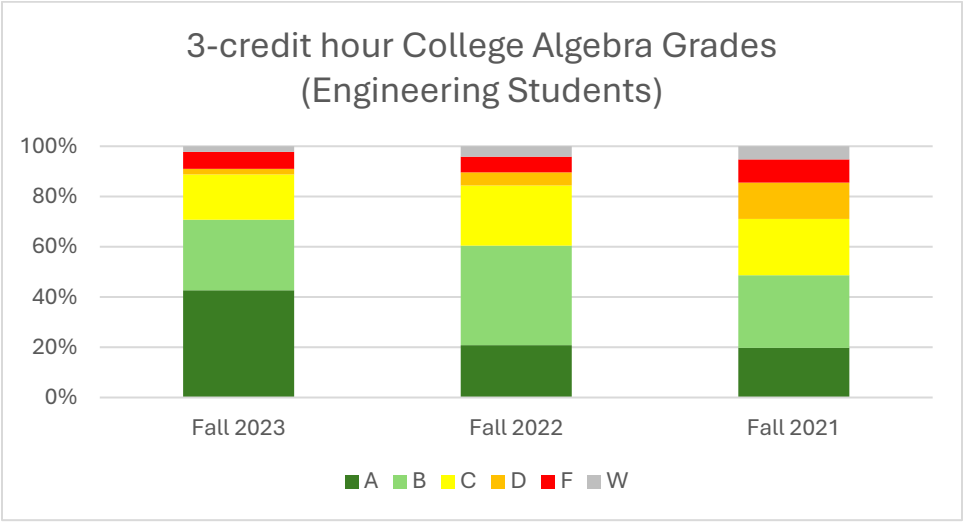

Figure 4. Engineering student grade distribution by year in 3-credit College Algebra

Once again, expanding our analysis, we examined pass rates not only for College Algebra but also for courses dependent on algebra skills, such as Precalculus and University Chemistry I, taken after completing College Algebra. Additionally, we included Fundamentals of Success in Engineering Study, which is the course our first-year engineering students enrolled in college algebra take before advancing to Introduction to Engineering I.

Table 3: Pass rates for First-year Engineering Students enrolled in 3-credit hour College Algebra and Precalculus and Chemistry I after completing 3-credit hour College Algebra. * indicates significant difference.

Pass Rates (Engr students only)	3- credit hour College Algebra (3CA)	Precalculus after 3CA	Chemistry I after 3CA	Success in Engr Study during 3CA
Fall 2023 Cohort	88.8%	80.0%	52.3%	89.9%
Fall 2022 Cohort	84.4%	76.1%	54.7%	87.5%
Fall 2021 Cohort	71.1% *	89.1%	54.0%	77.3%
3-yr total	82.0%	80.7%	53.6%	85.4%
Total n	261	187	179	260
Chi-Squared test (p)	0.0096	0.211	0.962	0.058

With smaller sample size, the Chi-Squared test with a post-Hoc analysis showed the only discernable variance was the College Algebra pass rates in 2021 were significantly lower than the 3-year average.

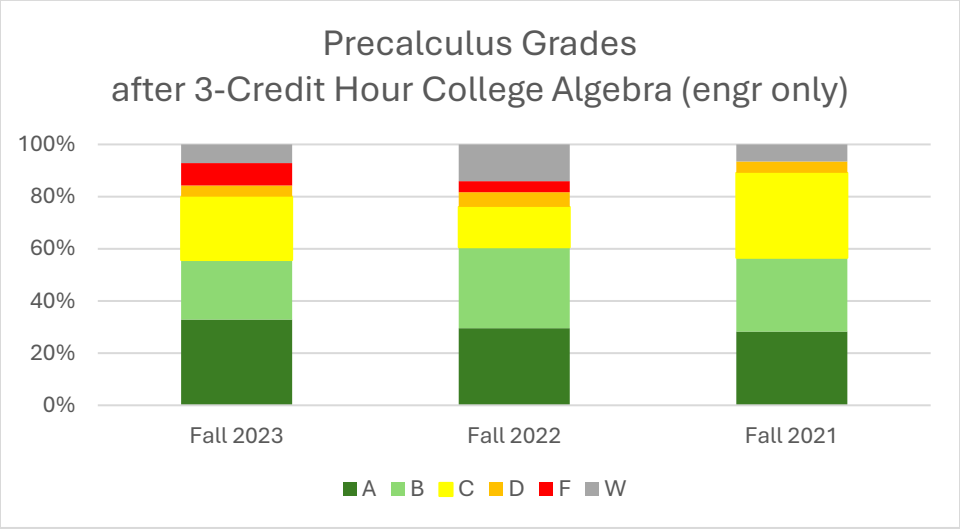

Figure 5. Grade distribution by year for engineering students in Precalculus after 3-Credit Hour College Algebra.

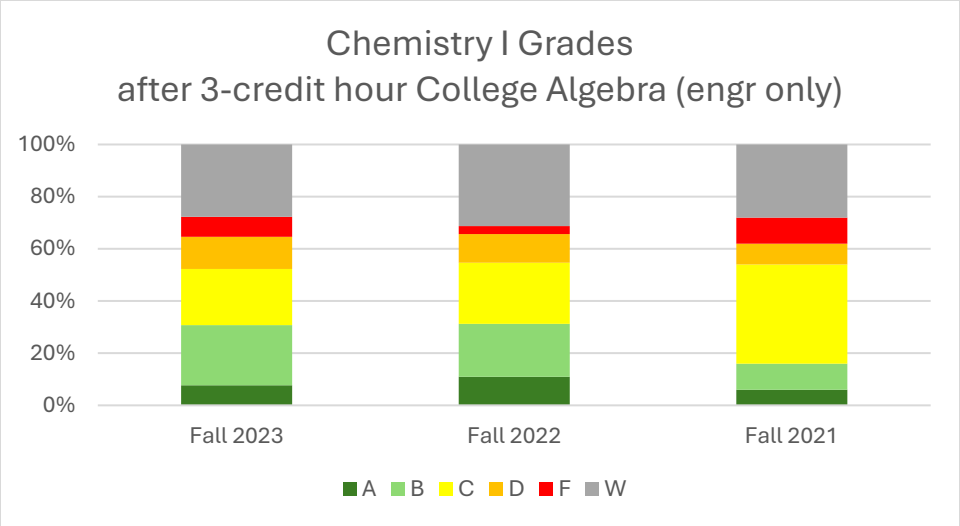

Figure 6. Grade distribution by year for engineering students in Chemistry after 3-Credit Hour College Algebra.

As with the general population, we observed some changes in Precalculus and University Chemistry I grades over the period studied. However, these changes did not reflect significant improvement like we would have hoped. As for Fundamentals of Success in Engineering Study, grades showed some improvement but were not statistically significant.

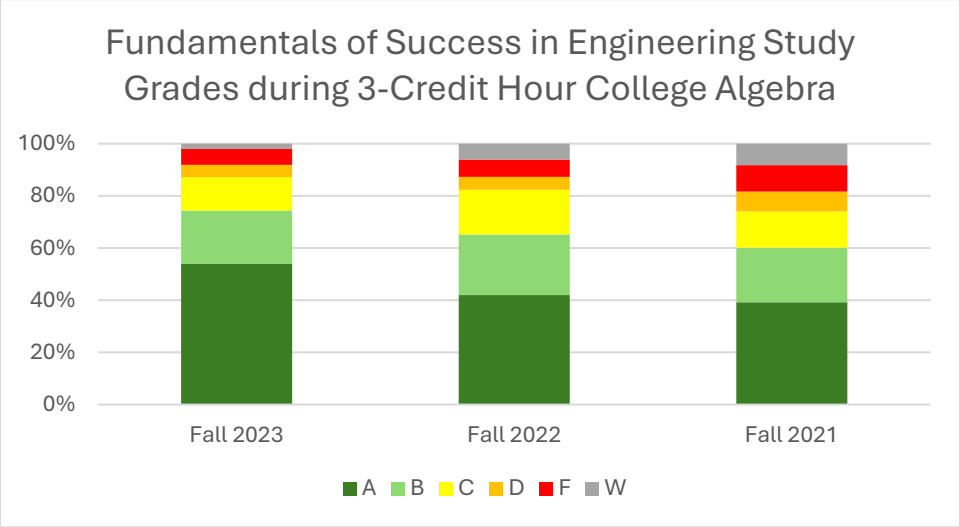

Figure 7. Grade distribution by year for engineering students Fundamentals of Success in Engineering Study during 3-Credit Hour College Algebra

Another way to examine the grade distribution is to look at the grade-point-average of students who completed all four examined courses: College Algebra (3-credit hours), Fundamentals of Success in Engineering Study (1-credit hour), Precalculus (4-credit hours), and Chemistry (3-credit hours). Obviously due to various pass rates of each not all students attempted all four of

these. Among those that took all four, there is a slight increase in GPA which corresponds to the increased A grades in College Algebra.

Table 4: GPA in College Algebra, Success in Engineering Study, Chemistry, and Precalculus among students that completed all four.

Year taking 3 CA	N	College GPA in four measured courses
23-24	63	2.58
22-23	61	2.52
21-22	43	2.52

A lingering question was whether the change of qualification for the college algebra courses would affect students. As mentioned, the Department of Mathematical Sciences introduced a high school GPA of 3.7 as an alternative qualification for the 3-credit hour College Algebra course, cutting the need for ACT or SAT scores. However, among engineering students, we do not see a significant change in average GPA or ACT for students in 3-credit hour College Algebra. This suggests that the removal of test scores then does not change expected outcomes for College Algebra.

Table 5: High School GPA and ACT Scores for Engineering Students in 3-Credit Hour College Algebra

Year taking 3 CA	N	High School GPA	ACT
23-24	89	3.66	21.9
22-23	96	3.63	23.2
21-22	76	3.53	23.3

Conclusions

The transition from MyLab Math to ALEKS in Fall 2023 significantly increased pass rates in the 3-credit-hour College Algebra course, with the percentage of A grades more than doubling. This improvement allowed more students to progress to Precalculus and University Chemistry I. However, despite higher College Algebra pass rates, success rates in these subsequent courses did not show significant changes, suggesting that changing the online platform did not lead to a stronger foundation in algebra alone or translate to improved performance in higher-level STEM courses.

From an administrative perspective, the transition to ALEKS streamlined coordination within the Department of Mathematical Sciences, aligning all College Algebra courses under a single platform. Additionally, since the UA's Math Placement Exam already utilizes ALEKS, students who attempt placement testing gain familiarity with the system before enrolling in their first mathematics course. However, this advantage does not extend to Precalculus, which uses a different platform, or to Chemistry, where the structure and implementation of the Pearson system differ significantly from its previous use in College Algebra.

For the College of Engineering, the effect is minimal. While the increase in College Algebra pass rates is encouraging, its long-term effects on engineering student retention and academic success require further study. Future research should explore whether improved performance in College Algebra fosters better problem-solving skills, greater confidence in math-intensive coursework, or higher retention rates in engineering programs. Thus far there is only one cohort of new students to study. We can keep monitoring these situations to see if higher grades in College Algebra translate into further improvements.

Ultimately, there is no single "magic bullet" that guarantees student success in algebra, but the Department of Mathematical Sciences has taken a meaningful step toward improving student outcomes. Continued monitoring and adaptation of instructional strategies will be essential in ensuring that these changes lead to lasting academic benefits.

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