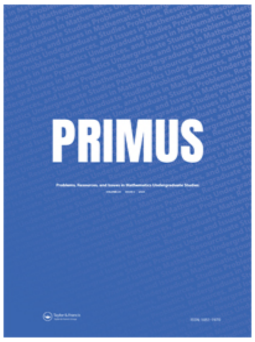

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PRIMUS
Problems, Resources, and Issues in Mathematics Undergraduate Studies

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/upri20

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To cite this article: Jill Faudree, Julie McIntyre & Ryan Bridges (30 May 2024): Using Data to Sustain and Measure Student Success Initiatives, PRIMUS, DOI: 10.1080/10511970.2024.2352355

To link to this article: https://doi.org/10.1080/10511970.2024.2352355

Published online: 30 May 2024.

PRIMUS
https://doi.org/10.1080/10511970.2024.2352355

Using Data to Sustain and Measure Student Success Initiatives

Jill Faudree, Julie McIntyre, and Ryan Bridges

ABSTRACT

This is a follow-up to an earlier case study [Faudree, J. 2021. Courage by experiment, rescue by data. *PRIMUS*. 31(3–5): 483–491.] describing one Math Department's attempt to improve pass rates in Calculus I by implementing the recommendations from national studies of successful calculus programs [Bressoud, D. and C. Rasmussen. 2015. Seven characteristics of successful calculus programs. *Notices of the American Mathematical Society*. 62(2): 144–146; Rasmussen, C., J. Ellis, and D. Zazkis. 2014. Lessons learned from case studies of successful calculus programs at five doctoral degree granting institutions. In *Proceedings of the 17th Annual Conference on Research in Undergraduate Mathematics Education*, pp. 999–1005. Denver, CO.]. This article, along with the earlier one, provide concrete, detailed strategies for promoting departmental change. We describe how the collection and analysis of baseline data has formed the backbone of a sustained, department-driven effort to improve outcomes for undergraduate students and one that weathered the pandemic. For context, our public university is the major research institution of the state, but it is also open-admissions, small (7500 undergraduates) and physically isolated. The effort described here started in 2016 with few resources: no faculty with expertise in mathematics education at the post-secondary level, no support from administration, and no external funding.

KEYWORDS
Baseline data; coordinated calculus; department change

1. BACKGROUND

1.1. Institutional Context

The University of Alaska Fairbanks (UAF) is the major research institution of the State of Alaska with seven campuses across the state and more than 8500 students of which about 89% (or around 7500) are undergraduates. UAF also operates as a community college, offering certificate and associates degrees, and is an open admissions institution. Located in the center of the state, the city of Fairbanks is the second largest in Alaska and 350 miles north of Anchorage. The Department of Mathematics and Statistics (DMS) has 17 permanent faculty. Of the 15 faculty with research components to their position, none have expertise in undergraduate mathematics education.

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Because UAF has an emphasis in engineering and science, Calculus I is a required course for many students and is taught every semester in both in-person and asynchronous online modalities. From 2016, when we began this study of Calculus I, to the present (Spring 2023), on average 200 students enrolled in Calculus I each academic year not including Summer semesters.

Between 2016 and the writing of this article in 2023, the COVID-19 pandemic was a significant stressor for the institution, its students and faculty. In addition, in July of 2019, facing $135 million in budget cuts, the University of Alaska system made national news when it declared financial exigency. In the past 6 years, our college has had four different Deans and almost no support (financial, logistical, or moral) for our student success efforts from administration external to the department. The story that unfolds below is one demonstrating that, when faculty choose to work together, meaningful success is possible even with few resources and significant challenges.

1.2. Research Context

The evolution of the Department of Mathematics and Statistics (DMS) at UAF as described in this article is given through the lens of three characteristics: course coordination, analysis of local data, and pedagogical shifts to active learning and corequisite instruction. Indeed, the results of national studies [3, 4, 10, 18, 19] indicated that course coordination, active learning in the classroom, and attention to local data were three of several characteristics of successful calculus programs, though their emphasis differed by type of institution [6]. These studies guided many math departments like DMS in their pursuit of improved outcomes in Calculus I.

Models of course coordination vary with the institutional context and culture [3, 19]. Recent scholarship has begun to document and classify the characteristics of influential and successful coordinators [15] and to articulate some of the mechanisms by which coordination and course coordinators act as change agents [20].

Corequisite instruction can be interpreted in many ways, one of which is the catalog-style course description in which a student may enroll in a target course only if they are co-enrolled in a second course (e.g., Calculus III is a corequisite for Physics II). More recently, the term corequisite instruction has expanded to include less formal arrangements in which students who are deemed underprepared for a desired target course are allowed to enroll in (or stay enrolled in) the target course provided they enroll in or participate in some added support. The added support may take many forms such as a course for credit, a workshop, or an expanded version of the target course. There are many examples of corequisite developmental math instruction in support of an introductory statistics course or liberal arts math course where the support does *not* take the form of a traditional 3-credit Elementary Algebra course [7, 14]. Instead the support is fewer credits and narrows topics to those immediately applicable to the target math course. Recently, scholarship studying which corequisite structures are most effective has begun to emerge [7].

Evidence of the effectiveness of corequisite models is sufficiently positive that both the Mathematics Association of America (in 2020) [12] and the American Mathematical Association of Two-Year Colleges (in 2021) [1] published positions in favor of its exploration in developmental mathematics education. A random controlled trial at three CUNY community colleges [14] and a follow-up study [13] demonstrated significant increases in college-level mathematics course completion when corequisite support was concurrent with a transition to alternative math pathways as compared with the traditional pathway starting at Elementary Algebra with College Algebra as the target course. Using data from 13 community colleges in Tennessee as all those institutions made a state-mandated transition to corequisite developmental instruction, a study [17] using differences in regression discontinuities also found significant gains in gateway math course completion and demonstrated these gains were largely driven by pathway realignment. The fact that several large state systems have made a wholesale transition toward corequisite developmental instruction and found significant positive effects despite widely varying implementation of this model speaks to the power of this strategy [7, 8, 16].

However, there are two crucial limitations to the studies above that are relevant to a corequisite model targeting Calculus I and STEM students. All of the studies above involved corequisite instruction of developmental mathematics in support of passing a single college-level mathematics course of any type. Moreover, every study, no matter how positive, found the effects of corequisite support diminished over time. Consequently, the effectiveness of corequisite instruction at the precalculus level in support of Calculus I for a student who must pass two additional semesters of Calculus and Differential Equations is less clear.

2. CALCULUS I STUDENT SUCCESS INITIATIVES: PAST TO PRESENT

For more than a decade, DMS has concentrated on improving passing rates in Calculus I which typically range between 50% and 60%. National studies of successful calculus programs [2, 3, 4, 6, 18, 19] guided our approach. While we are cognizant of more subtle measures of success, the reality is that administrators at our institution will judge our success exclusively via passing rates and we are sensitive to the fact that earning a grade of C or better in Calculus I radically increases the number of majors open to a student. Moreover, no one in our department has the expertise to implement rigorous qualitative studies.

While a DMS-wide emphasis on improving outcomes in Calculus I began somewhat earlier, the collection of the type of data described here began in Fall of 2016 and this is where the description will begin. In that semester, all in-person sections of Calculus I agreed to incorporate the same proctored online test of prerequisite knowledge at the beginning of the second week of class. In Fall of 2017, DMS moved to tightly and collaboratively coordinate all sections of Calculus I for 2 years as an experiment. The details of this process and its outcome can be found in the original case study [9]. The two points to emphasize here are that DMS choose to extend the experiment and that coordination increased the use of active learning strategies. For example, Calculus I instructors increased the use of group work in class and all incorporated mastery-based assessments. So, even in the face of reduced resources and enormous uncertainty due to financial exigency, DMS felt that the extra resources coordination required was worth it and we observed first hand that an experiment directed at assessment-level coordination had in fact produced pedagogical shifts.

When the pandemic hit UAF during March of 2020, the existing coordinated structure and the wealth of resources accumulated over the previous five semesters made the transition to online instruction almost easy for Calculus I. Indeed, by March 2020, 9 of 17 permanent faculty had taught coordinated Calculus I at some point. Well-developed habits of collaboration among faculty made sharing material, expertise, concerns, and suggestions instinctive and natural. Students volunteered that their math classes were the first to appear online, had the most resources and were the easiest to navigate.

In Spring 2021, UAF received an NSF grant (see https://www.csieve.org/) to support a 2-year experiment incorporating corequisite precalculus instruction in all our Calculus I courses. Thus, for the past 2 years, in addition to coordinating Calculus I and continuing to build materials that are supportive of students and faculty interested in using active learning, we added corequisite precalculus instruction.

Because the experiment just finished, a rigorous statistical analysis of the whole 2 years of data is not complete as of the writing of this article. However, a preliminary analysis limited to the first year of data indicates our efforts improved passing rates for many students [5]. The preliminary results will be discussed in more detail in Section 4.

As with the earlier experiment in coordination, DMS chose to extend the recent experiment in corequisite instruction for another year at least in part to make a decision informed by the full analysis. Also, DMS is implementing department-wide changes to precalculus, Calculus II, and Calculus III, all of which were informed by the lessons learned from the Calculus I experiment.

2.1. Brief Description of the Corequisite Model

Students identified as in need of extra support were required to attend an extra 1.5 hour class devoted to reviewing the precalculus content to be used in Calculus in the coming week. In the support class, students worked in groups at white boards with a graduate student teaching assistant as moderator. On quiz days, they were also required to spend time (up to 30 minutes) going over their quizzes immediately after taking them to correct their mistakes. Quiz corrections are also completed in groups.

There are two ways in which the structure used here appears different from those described in Section 1.2. Here the corequisite instruction is provided for students who *placed* into Calculus I, their target course, as opposed to providing the corequisite instruction to those who place *below* their target course. In fact, since UAF does

Table 1. Legend of Terminology.

Label		Description
Baseline	Readiness	Proctored ALEKS PPL score
	ESE	Completion of first few assignments
Success	Routine skills	Proctored, mastery-based differentiation/integration skills
	Final exam	Proctored, common, commonly graded
	Letter grade	Common syllabus, by instructor consensus

not proctor its math placement test, students effectively self-place and the majority of students gain access to Calculus I via this method. In essence, UAF has made the decision that if a student has precalculus on their transcript anywhere, they can enroll in Calculus I, which is not unlike community college policies requiring all high school graduates be allowed to enroll in a college-level math course. What is different is *when* students are identified as being in need of additional support. In most corequisite models, this occurs at registration. In our model, it occurs in Week 2 of the semester.

3. DESCRIPTION OF DATA COLLECTED

We only collected data for Fall and Spring semesters; Summer sections were excluded as they were not, generally, coordinated. All the data discussed here is the sort that any department that chooses to work together can collect. In fact, DMS collected much more data than mentioned here such as demographic data, crucial to addressing issues of equity. However, as important as this is, it may be unrealistic for many departments since the collection of this sort of data greatly increases the complexity of an experiment and likely requires substantial buy-in and expertise external to a department. Our measures fall into one of two categories: baseline student characteristics at the beginning of the semester or student success at the end of the semester (Table 1).

For 10 of 14 semesters from Fall 2016 to Spring 2023, every student enrolled in Calculus I was required to take a proctored ALEKS PPL assessment at the beginning of the second week of class. ALEKS PPL is an online, adaptive math placement tool and is widely used for this purpose, though it is not always proctored. The score on this assessment is used as a baseline measure of student mastery of precalculus content knowledge, or *readiness*, for short. Note that the readiness score was not used for *placement*. Students, instead, placed in Calculus via an unproctored placement test, coursework, or other miscellaneous methods. While it is common to use ACT scores, SAT scores or institutional placement tests as a measure of readiness, embedding a common, proctored measure into all sections of a course guarantees the measure is current and consistent for all students over multiple years.

For all 12 semesters from Fall 2017 to Spring 2023, all students in all in-person sections of Calculus I and most asynchronous online sections took several common, commonly-graded proctored assessments including two mastery-based assessments of routine differentiation and integration skills and a final exam. The weight of these assessments in the overall grade was also the same for all students.

In addition, the assessments in the first 2 weeks were low-stakes and designed to encourage early success such as homework problems graded on completion with multiple attempts and solutions available, a syllabus quiz, and/or a first pencil and paper quiz where students are given practice quizzes with solutions in advance. Using a handful (2 or 3) these low-stakes assignments given in the first 2 weeks, each student was assigned an additional baseline score called *Early Semester Engagement* or ESE for short. The ESE score is binary: 1 if all assignments in the first 2 weeks are completed or 0 if one or more are not completed. The assessments determining the ESE score comprise less than 2% of the students' semester grade. Numerically, a student could earn a zero on all of the assessments used to determine the ESE score and still earn an A+ in Calculus I.

The move to online courses from the middle of Spring 2020 to the end of Spring 2021 required that all assessments were either unproctored or very inconsistently proctored. Thus all data from the second half of Spring 2020 through the end of Spring 2021 were eliminated from all analyses.

Information about the course including all materials such as quizzes, exams, and syllabi starting in Fall 2017 are publicly available at https://uaf-math251.github.io/.

4. THE ROLE OF DATA

The readiness data over 12 semesters (Figure 1) formed the foundation of our efforts to improve outcomes for UAF students as it demonstrates how mathematical readiness has been declining over time and that this decline predates the COVID-19 pandemic. Ordinary least squares regression was used to model mean ALEKS PPL scores for 887 Calculus I students over 8 semesters. It yielded an estimated slope coefficient of -1.028 ($p < 0.01$), indicating a decrease in average ALEKS PPL score of slightly over a point per semester [5, 11]. The analysis corrects a tendency to assume populations of students are the same from 1 year to the next or to immediately attribute to the pandemic any observed student knowledge deficits.

In addition, the readiness data was crucial to convincing DMS members to start and to continue coordinating Calculus 1. A detailed description of the data and consequences can be found in [9] but the key finding was that student readiness varied dramatically when disaggregated by section. The fact that two instructors in the same semester would have such different student populations illuminated the value of a collective effort.

Readiness data also motivated the adoption of corequisite precalculus instruction in Calculus I and formed the heart of the proposal to the NSF. This data has been crucial in measuring whether the intervention has been effective. A comparison of pass rates alone is clearly problematic given the changes in student readiness illustrated in Figure 1 and the disruption due to the pandemic.

Our models compare pass rates when controlling for both readiness and ESE scores. The binary variable of passing/not passing Calculus I for $N = 613$ individuals was modeled using logistic regression with three independent variables: proctored ALEKS PPL score, cohort indicator (before or after the availability of

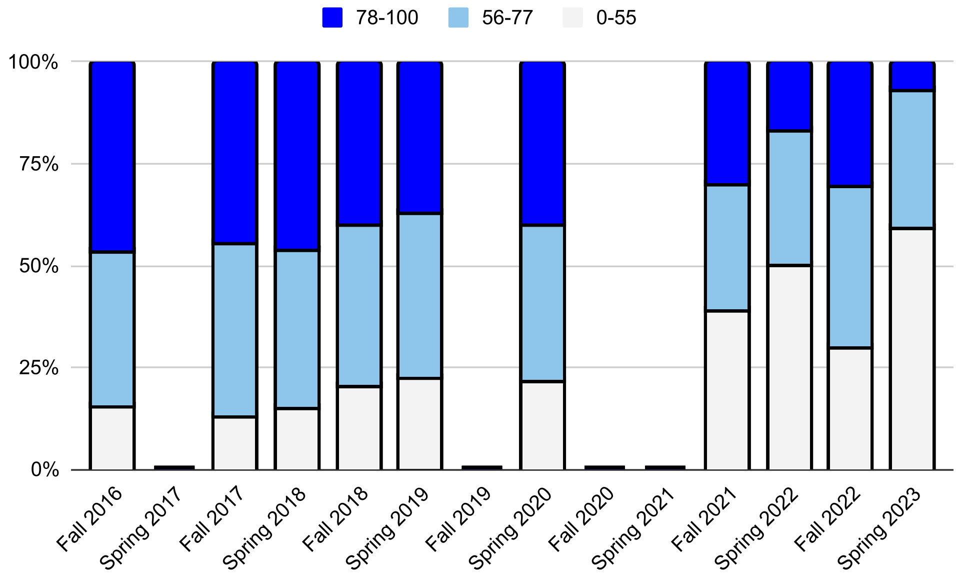

Figure 1. Proctored ALEKS PPL scores over time for $N = 1023$ Calculus I students over 10 semesters. Each column corresponds to the population of students enrolled in Calculus I in a given semester. The colors in a column indicate the proportion of students with proctored ALEKS PPL scores in the given range. Scores 78–100: ready for Calculus I, Scores 56–77: ready for Precalculus/Trigonometry/College Algebra, Scores 0–56: ready for a course below College Algebra.

embedded precalculus support), and ESE score (0 or 1). While this analysis is only preliminary, the exponentiated coefficient associated with cohort was 2.0 ($p = 0.0118$). Thus, the model estimates that the odds of passing Calculus I, among students with the same ALEKS PPL and ESE scores, were twice as high in semesters offering precalculus support compared to earlier semesters without this support. Figure 2 depicts pass rates before and after the availability of support for populations of students disaggregated by their proctored ALEKS PPL scores.

In addition, we used mastery-based assessments of routine skills to tease out possible grade inflation. Preliminary analysis strongly suggests that recent cohorts of students earning grades of B's and C's in Calculus demonstrate less proficiency at routine differentiation and integration when compared to earlier cohorts. Thus, at this point, we conclude that at least some of the increase in passing rates is due to changes in grading standard and not corequisite instruction. However, we did not see evidence of changing standards in final exam scores and, since these have been found to be excellent predictors of success in Calculus II, we also measured the success of the intervention using final exam scores instead of letter grades.

The binary variable of passing/not passing the Final Exam for $N = 548$ individuals was modeled using logistic regression with same three independent variables: proctored ALEKS PPL score, cohort indicator, and ESE score. The exponentiated coefficient associated with cohort was 1.59 ($p = 0.0797$).

The ESE measure was initially studied as a response to an institution-wide implementation of early warning reporting. There was much debate about how early such

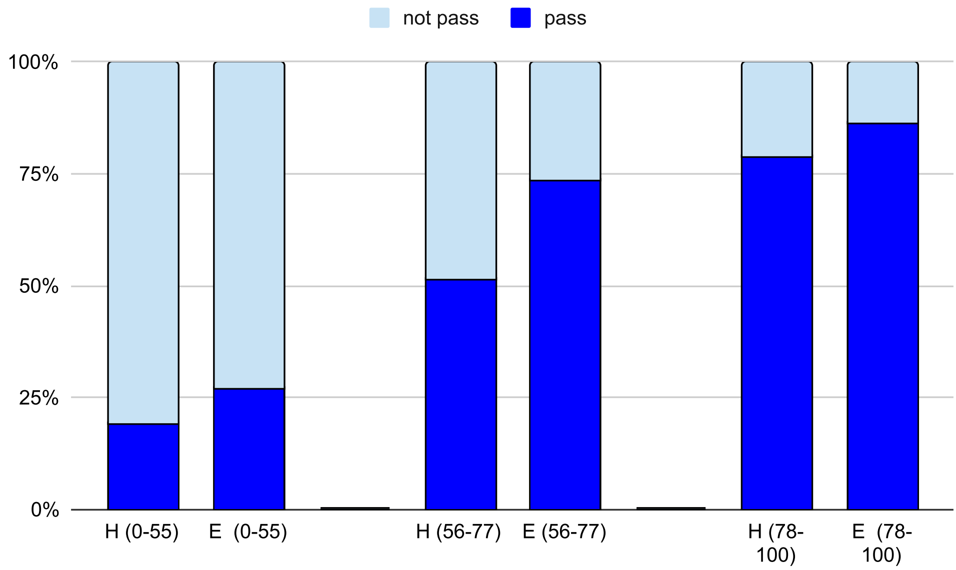

Figure 2. A comparison of passing rates in Calculus I for $N = 796$ students split into subgroups according to cohort and proctored ALEKS PPL score. Historical cohorts (H) had no extra support. For Experimental cohorts (E), extra precalculus support was available. Passing rates improved for all groups of students but gains were greatest for students demonstrating readiness for Precalculus, College Algebra or Trigonometry (scores 56–77).

a warning can be and still be meaningful. Of 710 students in Calculus I with ESE measures, 63% had an ESE score of 1 leaving 37% with ESE scores of 0, a nontrivial proportion of the Calculus I population. The passing rate in Calculus I for the 63% of students with ESE=1 was 71.4%. For the 37% of students with ESE=0, the passing rate in Calculus I was 36%. This crude and early measure – completion of a handful of assessments in the first 2 weeks – was considered significant in every statistical model we built. For example, in the same logistic regression modeling passing the final exam, the exponentiated coefficient associated with ESE score is 5.26 ($p < 10^{-11}$). Thus the model estimates that the odds of passing the final exam, among students with the same ALEKS PPL and the same cohort (with or without extra support), were five times higher for students with ESE=1 compared to those with ESE=0. The role of baseline student *behavior* (as opposed to baseline *content knowlege*) in student success will be an important measure to explore in the future.

Pass rates in Calculus I at UAF have not changed over the past 10 years, including the most recent four semesters in which corequisite instruction was added. Though few outside DMS acknowledge the subtle but profound accomplishment represented by stable pass rates in the context of a student population with declining mathematical skill set, DMS faculty see the win clearly.

5. CONCLUSION

In the face of many challenges and forces working in opposition to a collaborative, coordinated Calculus I course, every time DMS needed to decide whether to continue and improve or stop, the decision to continue has been unanimous. In each instance, the primary motivation for continuing has been the same: the data collected provides clarity on what is and isn't working. This clarity provides an anchor from which other initiatives can be tethered.

The choices to collect current, consistent baseline data on student mathematical knowledge and to frame each pedagogical change as an experiment whose success or failure requires measurement and analysis have proven to be durable and effective tools for motivating, measuring, and sustaining efforts to improve student outcomes. The investment in data collection and collaboration pre-pandemic paid significant long-term benefits that we could not have anticipated in Fall 2017.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author(s).

FUNDING

This work was supported by National Science Foundation.

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BIOGRAPHICAL SKETCHES

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