Addressing Math Readiness for Engineering and other STEM Programs

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Addressing Math Readiness for STEM Programs

Abstract

During the 2016 academic year, Methodist University found that our math sequence required some curriculum modifications in order to better support our growing Engineering Program. To meet the needs of incoming students, we created an Integrated Precalculus I course in conjunction with a new placement grid that incorporates both ACT/SAT math scores and the high school GPA for placement into the first semester mathematics course. This integrated course combines the College Algebra and Precalculus I courses so that students are on track for Precalculus II in the spring semester. Students are then ready for Calculus the following fall without the need for a summer course or delaying their studies unnecessarily.

This Integrated Precalculus I course was offered as a pilot program in 2017 and has now been offered for three consecutive years. Only students in the STEM majors of engineering, economics, chemistry, computer science, kinesiology, and mathematics are currently allowed to take the course as they all require some sequence of mathematics that involves courses that are only offered once a year. This is an ongoing project as we are still evaluating the course through student success in subsequent mathematics courses, retention in the major and at the university, and time to complete the mathematics sequence. We are in phase one of conducting the analysis by tracking each student in the new Integrated Precalculus I course as well as the traditional mathematics sequence. These students currently are enrolled in the Calculus sequence, thus the data presented is from completed MAT 1125 Integrated Precalculus I, MAT 1130 Precalculus, and MAT 1140 Precalculus II courses. The results are helping further evaluate the placement grid and approach to course topics, as well as what it means for recruitment and retention of non-math-ready STEM students (especially engineering). An upward trend in the average Integrated Precalculus grade while there is a downward trend in ACT/SAT math scores indicates the pedagogical changes have made a positive impact on these students' success. However, we did notice there are still concerns with the students right at the ACT/SAT placement cutoffs for both Precalculus I courses. We also discuss how it may help other institutions or high schools develop a curriculum without the need for multiple remedial courses.

Introduction

ACT/SAT Scores

Literature is indicating that drops in ACT and SAT scores are directly proportional to a drop in Math Readiness [1]. Education Weekly [2] reports that ACT scores show "troubling long-term declines in performance, with students' math achievement reaching a 20-year low. ... The average math score for the graduating class of 2018 was 20.5, marking a steady decline from 20.9 five years ago, and virtually no progress since 1998, when it was 20.6." Methodist University has also witnessed drops in regards to ACT and SAT mathematics placement scores with informal observations stemming from the need to add more sections of developmental and introductory Mathematics Courses (MAT 1030 Intro to College Mathematics and MAT 1050 College Algebra). In further exploration of the lower placement scores that were causing an increase in the number of students requiring the introductory mathematics courses, it was noted that many

students were just barely missing the MAT 1130 Precalculus I ACT/SAT math placement score used at Methodist University. In reviewing numerous incoming student transcripts, it was noted that this trend could be due to the number, level, and consistency of mathematics courses incoming students have completed prior to beginning their post-secondary school journey. Many students are finishing their high school career in an Advanced Functions or Algebra II mathematics course.

Methodist University began an Engineering Program in 2016 with no changes in the required mathematics sequence. As at other universities, if an engineering student (or any STEM student) is not prepared to start in Calculus their first semester, he/she must begin in the appropriate lower mathematics course according to their ACT or SAT math score. Even though a more formal mathematics placement mechanism would be preferable, Methodist University does not have the resources to implement a placement mechanism at this time. Thus, ACT or SAT math scores have been used. Furthermore, as a small, private liberal arts institution, Methodist University has limited offerings of many mathematics and engineering courses each year. This limitation on course offerings means that the mathematics sequence (each Calculus course is offered once a year) may delay an engineering student one or even two years depending on which mathematics course he/she takes during his/her first fall semester. In other words, incoming engineering students beginning in a College Algebra course will potentially be delayed a full year in starting their engineering coursework and two years towards graduation. These students are able to move on to Precalculus I in the spring semester, but then must either take Precalculus II in the summer or wait an entire year (the following spring) since Precalculus II is currently only offered in the spring semester at Methodist University. In order to help alleviate this delay for eligible students, faculty members from both engineering and mathematics have been diligently working towards a feasible solution that will meet the needs of our students as well as the unique limitations of our small institution.

Many of these incoming engineering students that were placed in College Algebra were also students that had ACT or SAT math scores that missed the set Precalculus placement requirement by a minimal difference. When these students then took College Algebra, we found many had experienced the material prior and had a recollection of the necessary mathematical procedures as soon as they were re-exposed to the topics. This basic recollection, however, illuminated the lack of mathematical readiness to excel at the Precalculus level where basics are not addressed and the content moves quickly to conceptual understanding with the need to apply one's mathematical understanding.

At Methodist University it was determined we required a solution that would 1) address the impact of beginning the mathematics sequence in College Algebra on the Engineering Program and 2) address the need for a brief review of the basic mathematical concepts taught in College Algebra to be included in the beginning of more advanced courses. In researching possible solutions, we had to keep in mind the size, capabilities, and restrictions of our small institution. The resulting solution was to create an Integrated Precalculus I course in conjunction with a new placement grid that incorporates both ACT/SAT math scores and the high school GPA for placement into the first semester mathematics course.

Readiness

When discussing overall mathematical readiness, we are referring to mathematical maturity, the ability to apply mathematical understanding to novel situations, and a confidence in mathematical ability. This is our informal definition. We noticed many students were lacking this mathematical readiness when placed in the College Algebra course versus the Precalculus I course. Many students were capable of tackling the procedural, basic skills, but lacked the conceptual understanding. We believe this lack of overall 'readiness' left the students unable to perform the more conceptual tasks on the ACT and SAT assessments, thus earning scores just below the set Precalculus requirements.

Methodist University Demographics

Methodist University is a small, private liberal arts university. Due to being a small institution, there are limited class offerings of upper level courses (2000 or higher). These limited offerings particularly affect the STEM fields. Regarding the STEM student population, 44% of the population is first generation and 50% of the population is from underrepresented groups. Regarding retention rates of STEM populations, we currently have a 54% First-Year STEM Retention Rate with a troubling decline to an 11% Four-Year STEM Graduation Rate.

Prior Curriculum Structure

The prior curriculum structure for incoming students placed into MAT 1050 College Algebra was as follows (and displayed in Figure 1):

1. Enroll and successfully complete MAT 1050 College Algebra Fall Academic Year 1
2. Enroll and successfully complete MAT 1130 Precalculus I Spring Academic Year 1
3. No Math Course Fall Academic Year 2 (based on successful completion of both College Algebra and Precalculus)
4. Enroll and successfully complete MAT 1140 Precalculus II Spring Academic Year 2
5. Begin the Calculus sequence Fall Academic Year 3

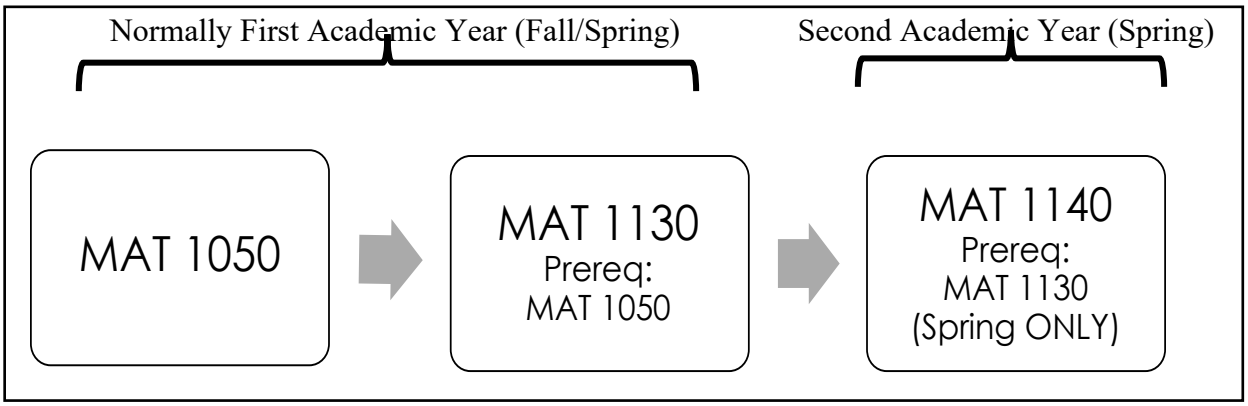

Figure 1: 2016 Course Catalog STEM Mathematics Course Progression

There are many factors in the above structure that hinder student success. First, engineering students do not begin the Calculus sequence, a four-course sequence, until Fall Year 3. Thus,

students starting in College Algebra would not complete the Calculus sequence until the Spring of Year 4. Many of the upper level STEM courses have Calculus I and/or Calculus II as a prerequisite or rely on an understanding of Calculus topics. This leaves the upper level math and some engineering requirements all occurring in Year 4. In addition, for students already beginning in an introductory course, a semester without a mathematics course is not beneficial. This break in mathematical learning also occurs in the middle of a sequence, between Precalculus I and Precalculus II, where a 9-month break is less than ideal.

Course Creation & Curriculum Restructuring

As mentioned earlier, the main step in the proposed solution that met the needs of both our students and our institution was to create an Integrated Precalculus I course. This course addressed the hindered progression through the many mathematics sequences required for the Engineering Program (as well as other STEM-related fields that required all or a portion of the Calculus sequence). It was created to bridge the gap between the MAT 1050 College Algebra course and the MAT 1140 Precalculus II course without requiring students to complete both MAT 1050 College Algebra and MAT 1130 Precalculus I. Table 1 lists the course outlines and comparisons for all three courses. The newly created MAT 1125 Integrated Precalculus I course was created for students who:

- Are enrolled in a Calculus Track STEM Major (Mathematics, Economics, Engineering, Chemistry, Computer Science, and Kinesiology).
- Scored too low for the Precalculus I ACT/SAT requirement.
- Met the MAT 1050 College Algebra ACT/SAT requirement.
- Displayed success in High School Mathematics classes with a solid GPA.
- Would gain from a brief review of College Algebra concepts.

Table 1: Course Outline/Comparison of MAT 1050 College Algebra, MAT 1130 Precalculus I, and the newly created MAT 1125 Integrated Precalculus I.

MAT 1050: College Algebra	**MAT 1125: (NEW COURSE) Integrated Precalculus I**	**MAT 1130: Precalculus I**
3 credit hours Fall, Spring & Summer	4 credit hours Fall Only (open only to Calculus Track STEM Fields)	3 credit hours Fall, Spring & Summer
• MAT 1050 covers most topics in MAT 1130 but lacks depth. • Includes Systems of Linear Equations • Does not cover polynomial functions above quadratics.	Covers all MAT 1130 topics & some basic MAT 1050 concepts which are considered preliminary knowledge to MAT 1130 Precalculus.	• Expands on all of the MAT 1050 topics in depth. • Includes polynomial and rational functions.
Progress to MAT 1130 Precalculus I	Progress to MAT 1140 Precalculus II	Progress to MAT 1140 Precalculus II

Table 2 briefly outlines the pedagogical differences employed in MAT 1125 Integrated Precalculus I, which differentiates the course from the traditionally taught MAT 1130 Precalculus I course. The main differences include the added lab hour for the brief review of the foundational and fundamental College Algebra concepts and the implementation of activities as

both group work and/or board work. These activities had students up, moving, conversing, and working together to complete tasks within the classroom and lab. Figure 2 provides an example of the simple additional reading/writing questions attached to particular content quiz questions.

Table 2: Pedagogical Differences of MAT 1130 Precalculus I and the newly created MAT 1125 Integrated Precalculus I

MAT 1130: Precalculus	MAT 1125: (NEW COURSE) Integrated Precalculus I
3 credit hours	4 credit hours
Traditional Lecture	Traditional Lecture with Group Work & Board Work Activities
On Average: 4-6 in-class content quizzes	Short daily content & reading/writing question quizzes
	Added One-Hour Lab with group/board work activities on fundamentals and foundational College Algebra topics
	Restricted smaller class size
	Restricted only to Economics, Engineering, Chemistry, Computer Science, Kinesiology, and Mathematics Majors

Homework Quiz – Other Types of Equations **NAME:** _____

MAT 1050: College Algebra **Score:** _____

1. Solve the following: $(x+1)^4 - 5(x+1)^2 = -4$	**a. Find a problem from the homework that would be solved using the same process.** **b. Without solving, what mathematical cues caused you to choose that particular problem from the homework. Answer in complete, concise sentences.**

Figure 2: Quiz Content & Reading/Writing Sample Question

Table 3 provides examples of other types of reading/writing questions that were utilized either on quizzes linked with content questions or within group activities that were completed either in the classroom or during the added lab component. One type of activity was a circuit activity as seen in Figure 3. The circuit activity was to be completed in lab, in groups, and at the board to earn credit. A linked follow-up reflection would have been a question similar to the Table 3 examples.

Table 3: Examples of Other Reading/Writing Activity Questions

Without solving, share a key step in solving an equation or inequality containing an absolute value expression?	Provide a written description for the Product Rule for Logarithms.
Without solving, share what tends to be a common error that occurs while solving equations containing radicals.	Your twelve-year-old brother is in a Math 1 online pilot course where his teacher posted a cartoon showing the number $\sqrt{-1}$. Your bother is familiar with square roots of perfect squares and is also fairly confident in basic arithmetic with positive and negative integers. However, he doesn't understand what $\sqrt{-1}$ represents. Provide your brother a written explanation that builds on his current math background.

Circuit Drill – Precalculus Review Name: _____

Directions: Start with #1 – the first cell, work the problem, and find the answer. Hunt for this answer amongst those stated in each cell and when found, mark this cell #2. Repeat. Try to be the first team to each cell. Make sure to show your work and justify your process mathematically. Continue to find answers to all 16 questions somewhere in the 'circuit' to advance to the next problem until the circuit is finished. Work together! Compare Circuits to insure correct completion.

Answer: $(x-3)(x+3)(x+6)$ # 1: Factor the polynomial completely. $24x^2-38x-11$	Answer: $2x^5$ # _____: Evaluate the expression. $2^4-3^2\cdot 5$

Figure 3: MAT Integrated Precalculus I Circuit Group Work Activity Example

The goal of the newly created course is that Calculus-track STEM students will enter the Calculus sequence earlier, thus allowing for a balanced progression through the required upper level mathematics and major courses over Years 3 and 4. Student involvement will occur earlier in the major due to prerequisite sequences in mathematics successfully being completed while still obtaining necessary prerequisite preparation. In addition, we predict that with successful progression through the prerequisite mathematics sequences and the STEM field coursework, an increase in retention and graduation rates for the STEM Major Programs will occur.

Current Curriculum Structure

The current curriculum structure, with the inclusion of the newly created MAT 1125 Integrated Precalculus I course, is displayed in Figure 4. Students that did not meet the requirements of the MAT 1125 Integrated Precalculus I course would still need to begin their coursework in MAT

1050 College Algebra. In this case, students were informed of the course structure up front and the possibility of a fifth year in the Engineering program.

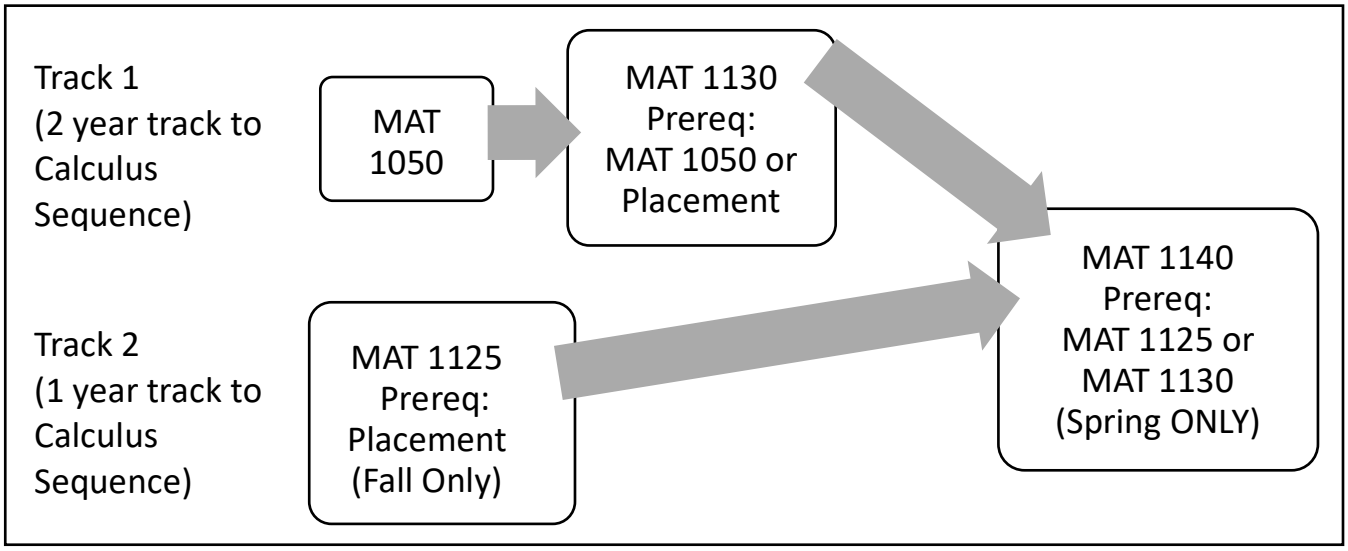

Figure 4: 2017 Course Catalog STEM Mathematics Course Progression

The Catalog Course Description is as follows:

MAT 1125 Integrated Precalculus I (4 s.h.)
Review of basic concepts of algebra, linear equations in one variable, quadratics equations, rational equations, equations involving radicals, equations with rational exponents, equations in quadratic form, inequalities, equations and inequalities involving absolute values, graphs and functions, polynomial and rational functions, exponential and logarithmic functions, and applications. Fall Semester Only. Prerequisite: Students majoring in Chemistry, Computer Science, Engineering, Economics, and Mathematics with (1) three years of secondary school mathematics, including two years of algebra and units in geometry and trigonometry and an appropriate math SAT/ACT score or (2) passing a placement test or (3) permission of the instructor.

DEPARTMENTAL GOALS:

1. Students will be adept at basic mathematical skills and mathematical reasoning.
2. Students who graduate with a major in Mathematics or Mathematics Education will be prepared to pursue advanced degrees in graduate school or pursue careers in teaching, industry, or a related field.

GENERAL EDUCATION/CORE CURRICULUM GOALS:

1. Students will demonstrate the skills needed for advanced studies in written and oral communication, mathematical reasoning, and the use of computers.
2. Students will demonstrate basic knowledge of the fine arts, fitness and wellness, humanities, mathematics, natural science and social science.
3. Students will demonstrate the ability to think critically about complex subjects.

Placement Matrix

The second step in the proposed solution, in conjunction with the creation of the MAT 1125 Integrated Precalculus I course, was a new placement grid that incorporated both ACT/SAT math scores and the high school GPA for placement into the first semester mathematics course. It has been noted in several studies that placement exams or simply using one measure of assessment is not proficient at placing students successfully within mathematics courses [3], [4]. This possibly incorrect placement has the potential of causing a negative impact if not caught early enough in the program, also then serving as a factor in declining retention and/or graduation rates. Research on what to use for correct placement has indicated that a combination of level of high school mathematics courses taken, overall high school GPA, ACT/SAT math score, and number of mathematics courses taken during high school shows a stronger correlation between success in the first university mathematics course than only using a mathematics placement exam [4]. In response to needing some form of placement, studies suggest using multiple measures, most widely that of the high school GPA and prior mathematics background in conjunction with assessment scores [5]. This research reports that combined measures have resulted in a higher percentage of correct mathematics placements. Again, although a specific mathematics placement mechanism would be ideal, due to the limitations of our university, like many small, private institutions, we need to use measures we already have access to such as GPA and ACT/SAT math scores. In fact, other institutions have found that the time and resource costs associated with developing and administering a valid placement exam do not translate to a significant improvement in student success over using other readily available data [6].

Prior to the newly created placement grid and newly created course, students were placed by the following ACT/SAT math scores:

- MAT 1050 College Algebra: SAT 510 or ACT 19
- MAT 1130 Precalculus I: SAT 530 or ACT 21

The placement grid proposed and in place since Fall 2017 for the Calculus Track STEM students is found in Table 4. This placement grid was determined by evaluating plotted data from the Methodist University Office of Institutional Research and Effectiveness regarding SAT/ACT math scores, GPA values, and successful course passing rates from prior semesters.

Table 4: Calculus Track STEM Placement Grid (revised 2017)

SAT / GPA	SAT <490 ACT <16	SAT: 490-530 ACT: 16-17	SAT: 540-570 ACT: 18-21	SAT:580-610 ACT: 22-23	SAT> 610 ACT> 23
GPA<2.7	MAT 1030	MAT 1030	MAT 1030	MAT 1030	MAT 1050
2.7<=GPA<3	MAT 1030	MAT 1030	MAT 1030	MAT 1050	MAT 1050
3<=GPA<3.5	MAT 1030	MAT 1030	MAT 1050	MAT 1050	1125 / 1050
3.5<=GPA<4	MAT 1030	MAT 1050	1125 / 1050	1125 / 1050	MAT 1130
4<=GPA	MAT 1030	1125 / 1050	MAT 1130	MAT 1130	MAT 1130

Placement of Engineering Students

Beginning with 2017 Summer Advising for the Fall 2017 semester, the Engineering Program began to use the new placement matrix for those students declaring engineering as their incoming major. In addition to the placement matrix, high school mathematics courses taken and the respective final grades in those courses were considered for all incoming engineering students no matter their ACT/SAT math scores following previous studies that indicate this method helps increase success in the first mathematics course [4], [5]. One final metric was implemented when students were still borderline for placement into MAT 1125 or MAT 1130 – the engineering advisor reached out to the individual student to explain the differences in the courses and gage his/her comfort level with mathematics. Students were then either placed in the course suggested by the placement matrix, moved up to MAT 1125 (matrix suggested MAT 1050), moved up to MAT 1130 (matrix suggested MAT 1125), or even moved down to MAT 1125 (matrix suggested MAT 1130). Those that were moved down barely meeting the MAT 1130 requirements and their high school transcripts showed limited high school mathematics courses or lower grades in completed high school mathematics courses.

Placement, pass/fail, and continuation data was collected for the three engineering cohorts that were placed into MAT 1125. As mentioned before, the placement matrix was used for initial placement, but then high school mathematics courses and communication with the student were further considered to possibly move a student up or down. Table 5 shows how many of the students registered for MAT 1125 were moved up from a lower mathematics course (to help get them on schedule) as well as moved down from the traditional MAT 1130 Precalculus I course. Data on how many students failed the course and whether or not they continued in engineering is listed as well.

Table 5: Placement Data for Engineering Cohorts in MAT 1125 since Fall 2017

Year	Total Students	Moved up to 1125	Moved down to 1125	Moved up Did not pass	Current Status of no-pass students	Moved down Did not pass	Current Status of no-pass students
2017	30	8	5	4	All left engineering	1	Left engineering
2018	20	5	3	5	All left engineering	0	N/A
2019	22	7	0	4	1 left engineering	0	N/A

Results

Data has been collected for the MAT 1125 and MAT 1130 cohorts since implementation in Fall 2017 (three cohorts of each) as well as the two cohorts that have completed MAT 1140. We have begun to use this data in placement and pedagogical improvements for the upcoming academic year. The next data we will begin to collect and analyze is continuation to the Calculus sequence, retention in engineering, and years to graduation.

Table 6 provides data on the average incoming GPA, average incoming ACT/SAT scores, the percentage of students that passed the course, the average grade (including those with failing grades), and the average passing grade. This information was split between the three cohorts and

the class, the newly created MAT 1125 Integrated Math I or the traditional MAT 1130 Precalculus I, each student completed. Figures 5, 6, and 7 provide a graphical display of the pass/fail results of all the 2017-2019 MAT 1125 Integrated Precalculus I and MAT 1130 Precalculus I students based on their incoming high school GPA, incoming ACT math score, and incoming SAT math score, respectively.

Table 6: 2017 – 2019 Cohort Student GPA, ACT/SAT, and MAT 1125 Integrated Precalculus I or MAT 1130 Precalculus I Grade Data

	2017		2018		2019	
Class	**1125**	**1130**	**1125**	**1130**	**1125**	**1130**
Average HS GPA	3.28	3.58	3.46	3.58	3.05	3.31
Average Math ACT	20.5	24.1	21.6	22.7	18.8	21.6
Average Math SAT	523	588	510	570	504	574
% Pass	76.5	89.2	37.5	77.6	46.7	72.4
Average grade	1.44 (D+)	2.42 (C+)	0.71 (D-)	1.69 (C-)	0.98 (D)	1.73 (C-)
Average passing grade	1.79 (C-)	2.72 (B-)	1.89 (C-/C)	2.23 (C/C+)	2.10 (C)	2.39 (C+)

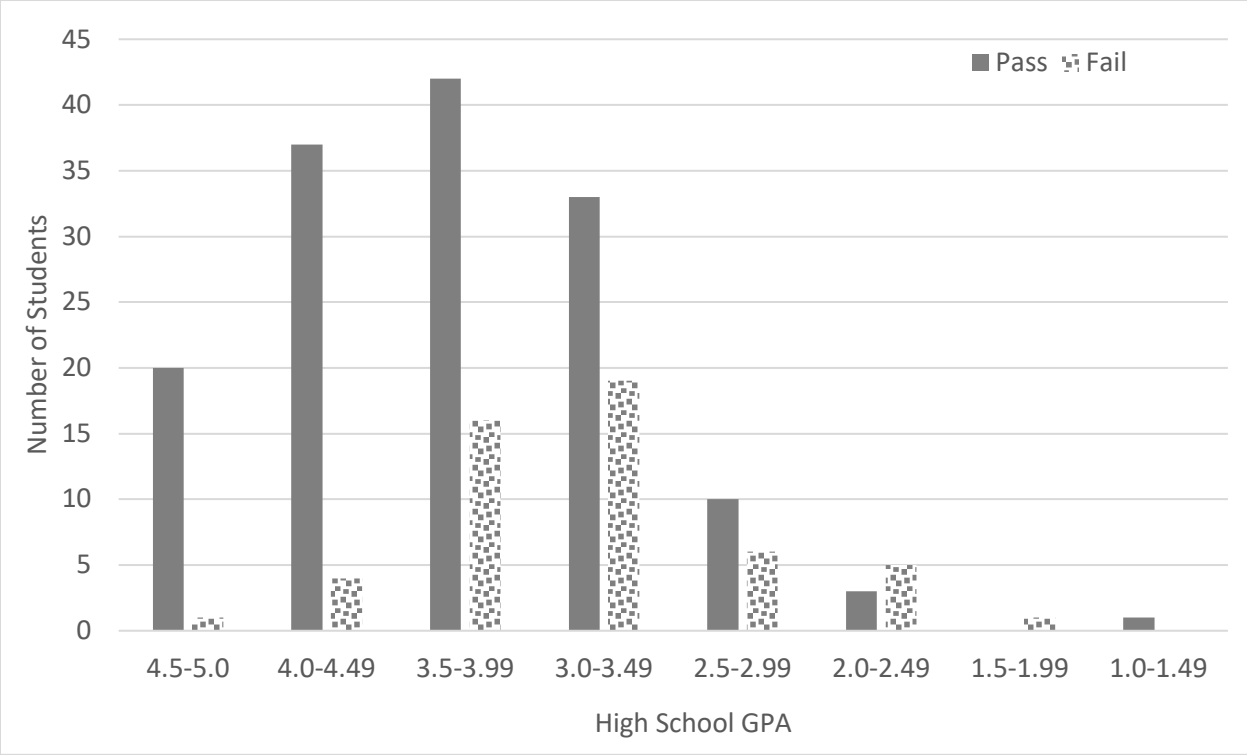

Figure 5: 2017- 2019 MAT 1125 Integrated Precalculus I and MAT 1130 Precalculus I combined Pass/Fail Results Based on Incoming High School GPA.

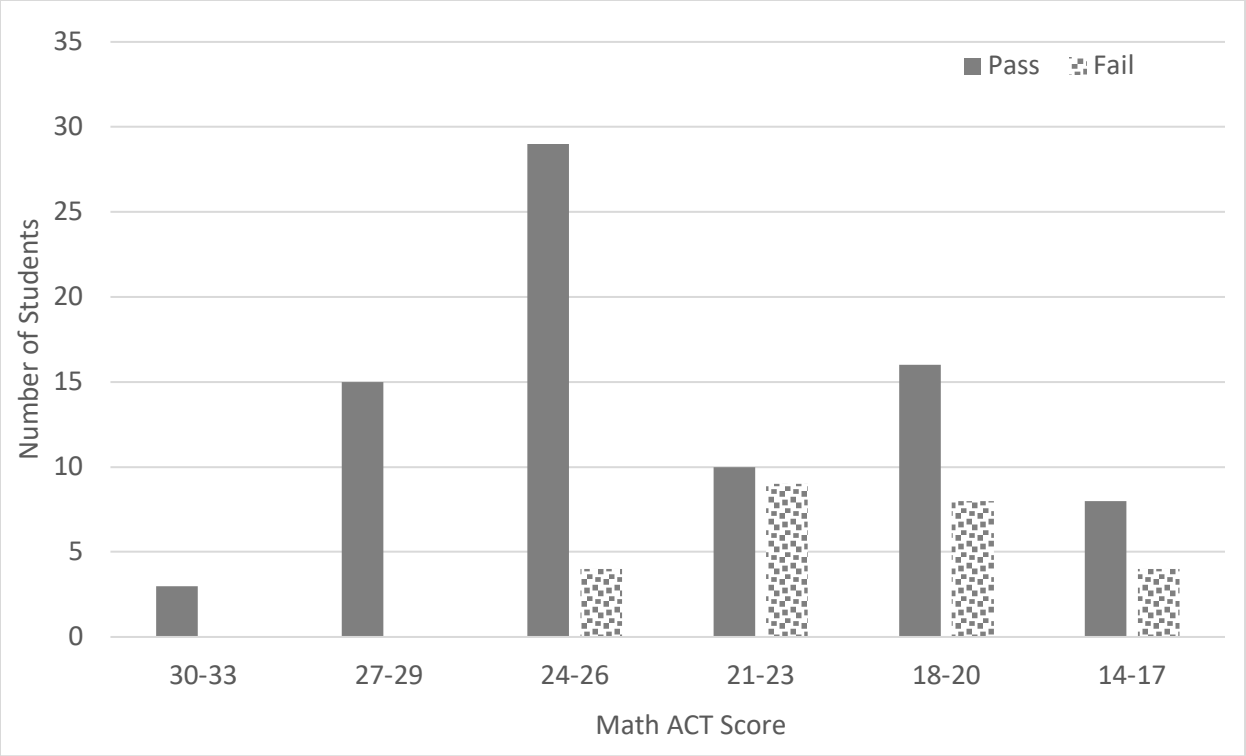

Figure 6: 2017-2019 MAT 1125 Integrated Precalculus I and MAT 1130 Precalculus I combined Pass/Fail Results Based on Incoming ACT Math Scores.

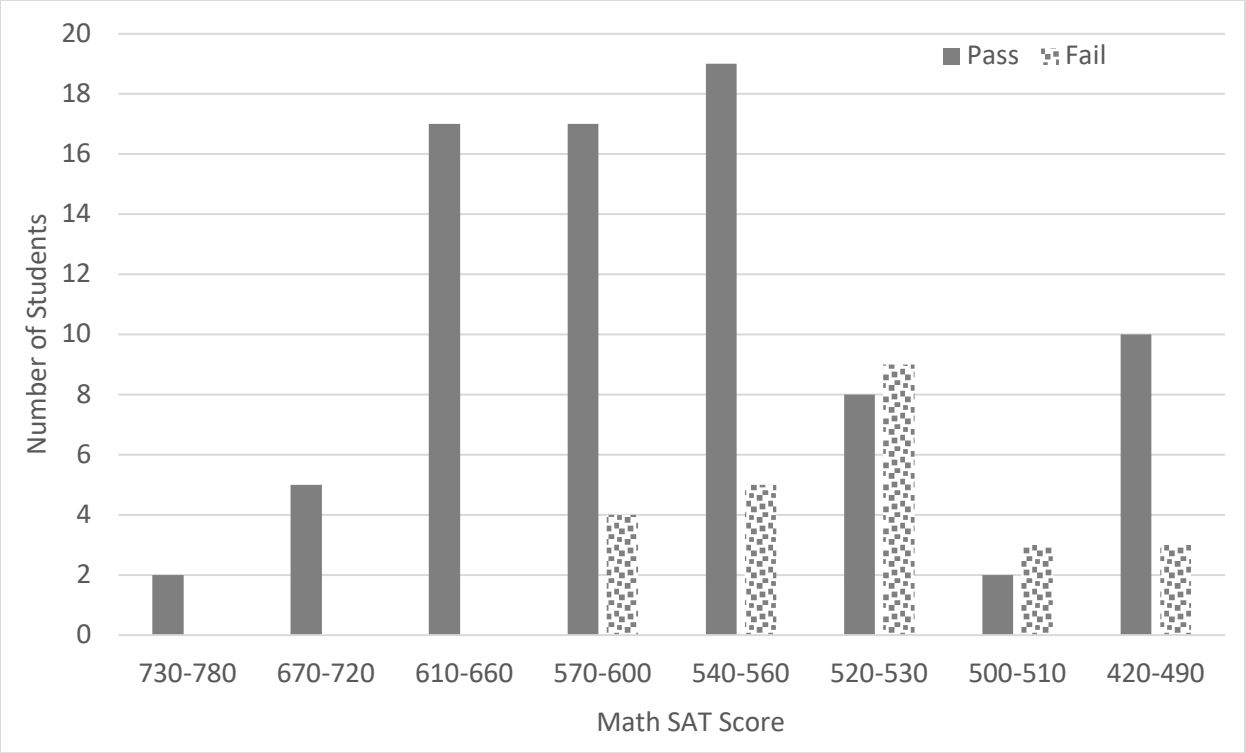

Figure 7: 2017-2019 MAT 1125 Integrated Precalculus I and MAT 1130 Precalculus I combined Pass/Fail Results Based on Incoming SAT Math Scores.

When creating the graphs for pass/fail based on ACT and SAT math scores, we noticed a higher proportion of students failing right around the ACT/SAT math score cut-offs for the two courses. Therefore, we created smaller categories in those ranges to focus on our current placement strategies.

Data was also collected on the first two cohorts' enrollment and completion of MAT 1140 (the third cohort was currently enrolled in MAT 1140 in Spring 2020). Table 7 shows the number of students that enrolled in MAT 1140 and course outcome (pass, fail, withdrew). Two things to note about the data:

1) The students that did not pass MAT 1125 or MAT 1130 but enrolled in MAT 1140 were enrolled in MAT 1130 and MAT 1140 concurrently during the spring semester.
2) The drops in MAT 1140 enrollment from MAT 1130 are due to students that took MAT 1130 but did not need any further mathematics courses for their major degree requirements, such as biology that only requires MAT 1130 and other non-STEM majors that only need one course at MAT 1050 or above.

Table 7: 2017-2018 1125/1130 Cohort Student Data for MAT 1140 Precalculus II

	2017		**2018**	
Class	**1125**	**1130**	**1125**	**1130**
# Enrolled 1140 (# Passed 1125/1130)	10 (13)	23 (58)	4[b] (3)	18 (45)
# Passed 1140	4	21[a]	1[c]	13
# Failed 1140	2	0	2	2
# Withdrew from 1140	4	2	1	3[d]

a – one student did not pass 1130; *b* – only one student passed 1125; *c* – student did not pass 1125; *d* – one student did not pass 1130

In addition to the quantitative results provided, informal observations made throughout the first phase of the study include:

- The creation of true cohorts within common math courses. Cohorts lead to study groups which then lead to learning communities, encouraging a sense of comradery amongst the students.
- Students are connecting and understanding the necessary math concepts earlier in the program with the immediate application of the trigonometry and calculus topics within their major courses.
- Students are personally connecting to the major discipline earlier due to having prerequisites completed sooner and, we believe, due to again having a 'cohort' in which to 'travel' through the program.
- Most students are still on track to graduate in four years.
- Within the institution, the Mathematics and Engineering Programs have developed a strong partnership. Communication between the two programs has grown through the course creation, placement of students, and monitoring of student progression. This communication has expanded into providing connections within additional course and program topics, as well as cross-listing a handful of upper level courses. The cross-listed courses enable focused students to earn a dual major in Engineering and Mathematics.

- The Mathematics and Engineering departments have created a team atmosphere amongst faculty, thus providing strong, consistent, and uniform guidance to our students. Research [7] indicates, particularly in the area of STEM retention, that relationships across STEM fields and "across departments can alleviate preparation deficits and lead to increases in retention in STEM fields." This team atmosphere is transferring down to the students and cohorts as they then naturally mimic the atmosphere around them and build their own learning communities as they progress through the program.

Discussion

From the data collected and provided in the results, we can see that our incoming students are following the national trend mentioned earlier [1], [2] by showing a decline in their ACT/SAT math scores. Therefore, students are beginning their educational journey with less mathematical maturity and less mathematical readiness. As STEM needs continue to rise, the challenge is to find a means in which to bridge the mathematical gap without adding years or numerous classes to the program. Our initial solution was two part: 1) create the MAT 1125 Integrated Precalculus I class and 2) revise the placement mechanism used to place students into classes. An analysis of the first phase data indicates that we are moving in the right direction to improve student success in mathematics and, in turn, retention. However, the data also indicates there are further steps that need to be taken, especially relating to the students that are right at the minimum placement ACT/SAT math scores or had a high school GPA of 2.0 to 3.49.

Placement Mechanism

Due to the limitations of our small, private liberal arts institution, we do not have the resources to implement a proven electronic placement mechanism. With that in mind, we have begun discussing the possibility of creating a traditional paper-and-pencil placement mechanism. However, this would take time due to the need to research what that would entail, what material is most indicative of success in Precalculus level courses, and then track results to determine validity. At this time, this is probably the most difficult intervention and is not a feasible immediate change. It has also been shown in previous research that a placement exam used in combination with other metrics only minimally increases student success [6]. For that reason, while discussing placement options, we are going to keep the current ACT/SAT math score information in conjunction with high school GPA and high school transcript information. We also do not believe a change in the placement matrix values for the ACT/SAT math score or GPA is necessary at this time. We are aware that a more formal placement mechanism would be ideal; however, even a more formal placement mechanism is not going to serve as a magic bullet to this increasing decline in math readiness.

We do recognize that the data from the first three cohorts shows those students right at the ACT/SAT placement scores of 19/510, 20/520, and 21/530 for MAT 1050, MAT 1125, and MAT 1130, respectively, appear to have a higher risk of failure in their first mathematics course. While one may believe we should increase the minimum scores so that these students are placed in a lower mathematics course, this will only continue to delay progression through the Calculus sequence, which we are trying to alleviate. Instead, we will continue to follow our placement

matrix, but evaluate the high school mathematics courses and GPA more closely during placement, especially for those students that also have a high school GPA of 2.0 to 3.49. Additionally, it was shown that it did not matter if these at risk students were enrolled in MAT 1125 or MAT 1130 – they still had a lower chance of success. In fact, the MAT 1130 average passing grade has dropped over the past three years while the MAT 1125 passing grade has risen slightly. We attribute these trends to the pedagogical methods used in MAT 1125.

Contact Hours and Presentation of Material

Even though the average math grade earned in both MAT 1125 Integrated Precalculus I and MAT 1130 Precalculus I declined from the first cohort (Table 6), we believe that is consistent with the overall decline in the incoming ACT/SAT math scores. What is notable and we are watching closely is the average grade earned of the students with passing grades. These results show the MAT 1130 Precalculus I students displayed a drop where the MAT 1125 Integrated Precalculus I students displayed a slight increase. We believe this is due to the increased contact hours with the MAT 1125 students due to the added lab and the shift in the classroom and lab pedagogy. With that in mind, we are in the process of investigating the feasibility of increasing contact hours with both courses. We are proposing MAT 1125 Integrated Precalculus I shift from a 4 credit/4 contact hour course (3 course hours/1 lab hour) to a 4 credit/5 contact hour course (3 course hours/2 lab hours). The proposed change would mean that students would meet with their instructor and have constant exposure to the material 4-5 days of the week, dependent on the lab arrangement. We are also proposing MAT 1130 Precalculus I shift from a 3 credit/3 contact hour course (3 course hours) to a 3 credit/4 contact hour course (3 course hours/1 lab hour) that would meet 3-4 days, again dependent on the lab arrangement. By including a lab in both MAT 1125 and MAT 1130, we are not only increasing the contact hours they have with their instructors, fellow classmates, and thus immersion in the content, we are also increasing the time away from traditional lecture as 'labs' provide a natural atmosphere for group work, board work, and meaningful mathematical interaction. As supported by previous research [8], inclusion of more active learning techniques should result in an increase in performance as we believe we are seeing with those students passing MAT 1125. Active learning methods have especially been successful in small classrooms – our classes are a maximum of 30 students [8]. However, transitioning to more contact hours and active learning strategies will require buy-in from all those involved.

Transition to New Structure

Measures we could employ to assist in making this transition would include: 1) initiate a bi-weekly or monthly (at the minimum) informal interdepartmental pedagogy and best practices sharing session, 2) employ the current SI – Supplemental Instructor tutoring service to the MAT 1125 and MAT 1130 courses, and 3) encourage fellow faculty to take advantage of the TLC – Teaching and Learning Center workshops provided through our institution. SI – Supplemental Instructor tutoring is currently being used in the introductory level mathematics courses. SI is a tutoring program where a current student, who can provide tutoring in the topic area, is assigned a course/instructor to work with within the classroom and provide additional tutoring hours outside of the classroom. TLC is the Teaching Learning Center on campus that provides monthly workshops for all faculty and staff sharing and supporting the best practices being used and

implemented nationally. Faculty are encouraged to create workshops for the entire campus community so we can learn from each other and share what has worked in our areas. As the Mathematics and Engineering Departments are already working closely on the MAT 1125/1130 course structures, faculty from both departments could host joint workshops on the activities used, lessons learned, and how to proceed in the future. The two departments could also host a workshop on identifying at-risk students and early intervention. Usually, students that are at-risk in one class are at-risk in several classes. Taking a more hands-on approach with these students in all classes should help improve performance in all classes and, thus, retention.

Early Intervention

Early intervention would be initiated for at-risk students as identified by their incoming GPA as the main indicator in conjunction with early informal observations by the instructor. When comparing the incoming GPA with pass/fail rates (Figure 6) it is noticeable that students with an incoming GPA of 3.49 or lower displayed more difficulties in the MAT 1125 and MAT 1130 courses. Our institution currently has a program known as ConnectU that allows for faculty, staff, and even fellow students, to identity students that may be at risk whether academically or personally. Once identified, our institution has a wonderful support system that identifies a team to work with the students. In this case, tutoring, weekly updates, and the formation of study groups would be some of the support mechanisms put into place. The intervention through ConnectU is usually initiated and carried-through by Student Services with some faculty involvement. Reporting of a student also usually occurs after a student has missed class or performs poorly in class. We would instead take a preemptive approach and identify these students at the beginning of the semester. Faculty would be made aware of the at-risk students in their classes so they could work to involve them more in class discussions and activities as well as be more aware of the work they are submitting. The mathematics faculty could then communicate with the students' advisors on progress and interactions in the classroom. As with athletics and the lower-level mathematics SI system, these students would also be placed on the at-risk list that would be required to attend tutoring sessions, faculty office hours, group learning sessions, or other activity to keep them involved with the material as much as possible. These activities would help the students succeed in their first mathematics course, but should also translate to future success in their next mathematics course and, finally, the Calculus sequence.

Performance in Subsequent Mathematics Courses

The MAT 1125 Integrated Precalculus I course was first introduced in Fall 2017 so the first group of students are just now completing their Calculus sequence and are entering Year 3 of their program. Therefore, we do not have sufficient data to make any conclusions on follow-through in the Calculus sequence or the student success. We have, however, collected data from the MAT 1140 Precalculus II course on the first two cohorts.

One thing to note is that we are seeing a high percentage of MAT 1130 students pass MAT 1140 despite the drop in the average grades for MAT 1130. We attribute this to the students that go on to take MAT 1140 versus those that stop at MAT 1130. The students in MAT 1140 are mainly from mathematics, engineering, computer science, chemistry, and kinesiology – the majors on campus that require a minimum of MAT 1140. This means the students taking MAT 1140 may

have a higher aptitude for mathematics and are those that are earning the higher grades in MAT 1130. However, we are not seeing the same success with the students that take MAT 1125. There are fewer students that take MAT 1125 than MAT 1130 since we want to keep that class small and, at present, only offer one section of MAT 1125; therefore, the data available is already limited. It becomes more limited for students in MAT 1140 that started in MAT 1125 as we are seeing lower passing rates than in MAT 1130. However, with those limitations, we are seeing that the MAT 1125 students are struggling with passing MAT 1140. A few reasons that we believe are contributing to this are:

1) While students are passing MAT 1125, they are doing so with a lower average grade. These students are most likely still not mathematically mature and thus struggle in MAT 1140. This probably also explains the higher rate of withdrawals.
2) There have been several students that did not pass MAT 1125 but are still registering for MAT 1140 while concurrently taking MAT 1130 (MAT 1125 was not offered in the Spring semester for the first three cohorts). The students are doing this to stay on-track with the mathematics courses, but it means that the more at-risk students are now trying to succeed in two mathematics courses at a time.
3) The MAT 1140 is lecture-based and these students came from an active learning class. It is possible that students are trying to adapt to the pedagogical change as well as the new material.

As students continue through the mathematics sequence, we will collect longitudinal data on the rates of success and add more robust MAT 1140 data as well as Calculus sequence data.

Future Plans

As mentioned earlier, the first cohort of students is just now entering Year 3, and we will soon be able to start analyzing the Calculus data once the sequence is complete. With this data we plan to:

- Track changes within the prerequisite mathematics sequences and their effect on retention and graduation rates in the STEM fields.
- Gain more formal data to support the MAT 1125 Integrated Precalculus I course creation and additional actions mentioned above.
- Continue to bridge the gap in mathematical readiness based on data driven results.
- Continue to support STEM field students through their four-year journey by accessing data driven program and student needs.
- Continue to build on the partnership and communication between the STEM fields.

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