# Work In Progress: Finding Correlation Between Multiple Math Placement Methods and Grades in First Math Courses for Freshmen Engineering Students in a New Engineering Program

**Dr. Jeffrey David Carvell, Marian University**

Dr. Jeffrey Carvell joined Marian University in January 2014 first as an adjunct instructor, then full time instructor, then tenure-track instructor, and now a tenured associate professor. Since 2016, Dr. Carvell has acted as the director of the Marian University Dual Degree Engineering Program (DDEP). His research and academic interests pertain to the area of nanotechnology, and its application across disciplines of physics, chemistry, biology, and engineering. He is interested specifically in the interactions between ferroelectric, ferromagnetic, and ferroelastic materials on the nanoscale, with emphasis placed on the applications of these materials to electronic devices. Dr. Carvell is also interested in research in engineering and physics education and has presented research on multiple topics in this area, with more projects moving forward. While at Marian, Dr. Carvell has taught eleven courses across the physics and engineering programs. He also received the Marian University Advisor of the Year and the E. S. Witchger School of Engineering Award for Service Excellence, both in 2022, and the E. S. Witchger School of Engineering Award for Teaching Excellence in 2023.

**Dr. Sarah Klanderman, Marian University**

Dr. Sarah Klanderman is an Assistant Professor of Mathematics at Marian University. She is an algebraic topologist and math education researcher, with interests including computations related to topological Hochschild homology, supporting underrepresented groups in STEM, connections between mathematics and other disciplines, and her work with undergraduate research students at the intersection of number sequences and graph theory.

**Salomon Turgman Cohen, Marian University**

Prof. Turgman has been teaching chemical engineering since 2013 and has experience teaching almost the entire chemical engineering curriculum. He got his undergraduate degree in chemical engineering from Purdue University, his Ph.D. from North Carolina State University, and completed a postdoctoral research experience at Cornell University. From 2013 to 2022 he was a faculty member at Kettering University were he was able to develop and evolve his teaching. In 2022 he moved to Marian University with the goal of launching the new chemical engineering program there. Prof. Turgman has a passion for computational problem solving and for interactive explanations. He believes that every time a learner gets a chance to interact with a topic, we create better opportunities for students to make connections and develop depth in their understanding.

# Work In Progress: Finding Correlation Between Multiple Math Placement Methods and Grades in First Math Courses for Freshmen Engineering Students in a New Engineering Program

**Abstract:**

This paper is a work in progress, evidence-based practice paper. The COVID-19 pandemic changed the way a lot of universities operate, especially in the area of student admissions. Prior to the pandemic, some universities were moving to a test blind approach to admissions. When the pandemic hit, many students were not able to take the ACT or SAT, and they were unable to provide scores. As a response, Marian University was forced to go test blind on admissions, and that policy was implemented permanently. At the same time as this change to test blind admissions, Marian was opening a brand-new school of engineering, accepting the first freshman class of engineering majors in August 2022. With a new school of engineering and an incoming freshman class, one of the most important pieces of work we had to start the year was to properly place the freshman students in an appropriate mathematics course. Marian uses our own math placement exam that students take online prior to students attending orientation. During orientation that first year, we noticed many of the incoming engineering students were placing into pre-calculus, even if they had taken AP Calculus or dual credit calculus in high school. We anticipate that most engineering students will start in at least Calculus I, so this seemed like an issue that needed to be solved. In the end, for the first two academic years the engineering program existed, we used a combination of the university placement test and high school courses and grades to place students into an appropriate math course. At the same time, during an introduction to engineering course that all freshman engineers take, students were required to complete a math placement test through ALEKS from McGraw-Hill. We will analyze the grades for all students in the math course into which they were placed to see what the best correlation between grade and placement method (ALEKS, university test, high school courses), as well as predicted outcomes in first year physics courses. We will also use this data to determine which method would be the best practice in subsequent years and classes.

**Keywords:** Math placement, Engineering program creation

## Introduction:

This paper is a work in progress, evidence-based practice paper. In the midst of the COVID-19 pandemic, many universities across the US were struggling, closing, or scaling back operations[1,2], especially private religious schools and small liberal arts universities[3]. At Marian University, instead of scaling back, we decided to take a major step forward, introducing a new school of engineering, with majors in mechanical, civil, chemical, biomedical, and computer engineering. Previously, the university had offered a Dual Degree (3+2) engineering

option. At the same time as this expansion, Marian  was making another major change. Due to the COVID-19 pandemic, many high school students were unable to take the ACT or SAT, and were therefore unable to report scores to our school. For that reason, Marian , like many across the country, opted to go “test blind” in admissions, and accept students without having reported scores for the ACT or SAT. While some universities have since gone back to requiring the tests[4], Marian  has remained test blind. When the university required SAT or ACT scores, math placement could be done using the math specific exam scores. Students with scores above a certain level were placed in Calculus I as appropriate. Under the previous dual degree engineering program, all students placed this way. But with an influx of new engineering students growing the number from about twenty freshmen to seventy in two years, combined with the change to a test blind admission system, Marian  needed to find a way to place students into math courses.

Engineering students typically start in Calculus as their first math course. The graduation rate for engineering students who start in pre-calculus has been reported as low as 20%[5,6]. Knowing this, and having gone test blind as a university, the next logical step was a math placement exam. Marian University had an existing math placement exam, which had been in use for at least the last 10 years. Prior to COVID-19, this test was typically only given to student who had low math test scores on the ACT or SAT. It consists of only multiple-choice questions, and students have one attempt at the placement exam. The exam is sent to students as a part of their new student orientation, and they do not take it until several days before they come to register for freshman year.

With the first class of incoming engineering majors, we looked at their scores on the math placement test. We found that out of thirty-seven students who took the placement exam, none placed above pre-calculus and into Calculus I. We had three students who took AP Calculus AB in high school but did not take the AP exam or did not score high enough to get credit. Even these students were not able to place into Calculus using our in-house placement exam. For lower math course, such as pre-calculus, college algebra, finite mathematics, and other such courses, the placement test seemed to work well, and the passing rate of students in their initial math class matched expectations. But knowing that the graduation rate for engineers beginning in pre-calculus was much lower than those starting in Calculus I, our engineering school knew we needed to explore other options.

At Marian, the math courses follow a different grading system. The classes use a mastery-based grading system instead of the traditional score-based grading system. This system will be explained further below. The use of this system was another consideration in evaluating our math placement at Marian. The School of Engineering decided to study several different methods of math placement over a two year period in order to see if there was a way to identify

which students were ready for Calculus I and were capable of succeeding in the mastery-based grading system.

**Mastery-based System Used in University Math Courses:**

In the calculus sequence at Marian, we use an alternative assessment technique referred to as mastery-based grading. Instead of providing points-based grades, students receive credit for each course learning target once they can demonstrate that they fully understand that topic. Because there is no longer any reward for partial understanding, there are multiple opportunities in various formats for students to provide evidence of their knowledge, including through writing assignments, oral explanations in office hours, as well as on in-class understanding checks. Further, these assessments often include revisions of previous work so that students can clarify any confusion and learn from their mistakes.

We used backward design to create these courses by establishing the learning targets (e.g., "I can compute the average rate of change of a function, explain the connection between average (AROC) and instantaneous rate of change (IROC), and interpret their meanings in context.") and then directly aligning all assessments to them. Work in these classes follows a scaffolded learning approach beginning with low stakes learning opportunities and building on students' expertise. In preparation for class, students complete class prep assignments that review prerequisite material and introduce them to new content for the first time. These assignments include an overview of learning outcomes, readings from the textbook, instructional videos, online practice problems (with multiple submission attempts), as well as deeper reflective questions. Class preps are graded based on effort (with explicit instructions to hand in all progress after 60 minutes maximum of work) and include both students' notes as well as questions they still have.

Class often begins with a discussion of common questions or mistakes the instructor observed on the class preps and then reviews and builds on those concepts. The bulk of class time is spent working collaboratively in pairs or groups on examples. This active learning is intended to clear up any remaining confusion by providing students with chances to communicate with both the professor and fellow learners. Often these discussions will center around student explanations and solutions as a way of preparing them for independent work. On homework, students may consult their notes, textbook, and other resources such as a tutor or the instructor. These assignments include multiple attempts and flexible deadlines and are considered complete once students earn an 80% or better. After the class preps and homework, there are in-class understanding checks (often in the form of quizzes or tests) as well as writing assignments. The writing assignments are done outside of class and include reflections as well as opportunities for students to demonstrate understanding on learning targets. The in-class

assessments are completed individually, without notes, but students are not penalized for any incorrect attempts. Each problem is aligned with a specific learning target, and a given learning target will appear on multiple understanding checks in order to provide extra opportunities and increase retention. For every learning target, once students fully and correctly justify their solutions twice, they have mastered that learning target.

Final grades are then calculated based on the number of (1) learning targets that they have shown that they have mastered, (2) class preps earned, (3) homework assignments completed, and (4) writing assignments completed. As mentioned above, all of these categories have multiple opportunities built into the class, often including flexible deadlines and revisions, and each letter grade is based on earning a subset of the total that are included in the class. Anecdotally, we find that students find this system to be much more transparent, that it allows for additional time for them to understand a given idea, and that it encourages growth mindset since students have multiples opportunities and can still be successful in the class even if they initially get things wrong. However, research also confirms many of these benefits from such grading schemes[7] in addition to documenting lower levels of stress and anxiety for students[8] and well as more control over their grades[9], even during the difficulties of the COVID pandemic.

**Data and Discussion:**

The difficulty in placing students into any math class, much less a mastery-based system as described above, is the multitude of options available. As mentioned previously, we could see that the placement test already in place at the university was not useful in placing students into Calculus I. When the school of engineering was established, we began to look at other options for placement into higher level math courses.

The dean of the engineering school, along with faculty from the engineering and math departments, began exploring testing options. We had meetings with multiple companies and representatives. After these discussions, we decided to use the ALEKS system developed by the McGraw-Hill company. ALEKS is an artificial intelligence-based system that can identify topics students are strong in and ones in which they struggle. During the meetings, the members of Marian thought that the way ALEKS assessed mastery of topics matched what we did in our math classes, so a transition may be easier. Additionally, ALEKS has other functionality that makes it a good option for Marian. It uses open-ended type questions instead of multiple-choice options, further showing mastery of topics instead of just random guessing. When a student completed the ALEKS exam, they got a score. For Marian, we set a score of 70 to place into Calculus I and 50 to place into pre-calculus. If a student did not achieve this score, ALEKS gave personalized reports showing topics that students mastered and didn’t. If a student saw a topic

they were weaker in, ALEKS had built-in modules that students could use to study those topics[10].

This ability to study topics led to one of the biggest advantages of ALEKS: students could take the exam multiple times. We set the limit to three attempts for Marian. If a student who scored below a 70 was able to score above a 70 on a subsequent attempt, they would still place into Calculus I. Unlike our institution exam, ALEKS took a more holistic approach instead of a single test administered during a set time. ALEKS could be taken at home, and we were able to share it with students before their new student orientation date, and they were able to place into higher level math classes much earlier.

With the use of ALEKS, we now had four methods of placing students into a math course at Marian. The first option was using the university placement exam described above, taken the week of new student orientation. The ALEKS exam was the second option, taken at some point, or multiple times as needed, during the summer prior to freshman year. Even with these options, some students did not complete either exam, and high school math courses and grades or AP scores were used to determine the appropriate math class. Finally, some students had dual credit or transfer credit prior to starting at Marian, and that credit was used to place into the next math class.

Since there were four placement options, comparing placement results would be difficult with missing data points if a student did not take one or both placement exams. In order to have complete data, all engineering students were required to complete the university placement test and the ALEKS placement test at some point during their first semester, as a part of their Introduction to Engineering class. This was included as a homework assignment, and students got full credit for having completed the exams. Data was collected based on placement method, and the grade in the first math course the student took at Marian. The data was collected for two years, classes starting in the fall of 2022 and the fall of 2023, for a total of ninety-four students. Using one of the above methods of placement, all freshmen engineers were placed into one of four math classes: intermediate algebra (remedial math), pre-calculus, Calculus I, or above Calculus I. We wanted to see if any method was a better predictor of grades or success in passing the first math class. As engineering students, the course sequence cannot continue if a student is not passing math classes.

Table 1 shows the student who placed into the remedial math course, college algebra. These students are typically advised that completing an engineering degree will be difficult since they are so far behind in math. Students only place into this class using the university placement exam. Very few engineering students should be entering the program placing below pre-calculus. This data shows that of the ninety-four students who entered the university with an engineering

major declared in the two years it has existed, only three students placed below pre-calculus, and the grades varied. As mentioned above, students are only placed here through the university exam.

## Table 1. Students placing into College Algebra

| Placed Via | Total # students | Grade of A | Grade of B | Grade of C | Grade of D | Grade of F | Withdrew |
|---|---|---|---|---|---|---|---|
| University Placement Exam | 3 | 1 | 1 | 0 | 0 | 1 | 0 |

Table 2 includes all the placement and grade data for the pre-calculus course. As expected, a larger number of students placed into this course, and were placed using either the university placement exam, ALEKS placement, or high school grades. For many of the students who placed into this level via another method, the ALEKS scores, taken either at the same time or subsequently during the Intro to Engineering course, matched the placement level.

## Table 2. Students placing into Pre-Calculus

| Placed Via | Total # students | Grade of A | Grade of B | Grade of C | Grade of D | Grade of F | Withdrew |
|---|---|---|---|---|---|---|---|
| High School Course/AP | 2 | 0 | 0 | 1 | 1 | 0 | 0 |
| University Placement Exam | 10 | 3 | 1 | 2 | 1 | 1 | 2 |
| ALEKS Placement Exam | 12 | 5 | 3 | 2 | 0 | 2 | 0 |

The grades in these courses seem to show that the students placing into pre-calculus via the placement exams, whether the university or ALEKS, performed at about the same levels. As expected with any course, the grades range from A to F with several withdrawals. Overall, 71% of the students who placed into pre-calculus passed with a C or better in the course and moved to the next math course in the sequence. This matches with percentages seen at other universities for this class[11].

The largest number of students entering Marian with a declared engineering major placed into Calculus I as their first math course at Marian. All methods of placement were used to place students into this class, and the corresponding grades are shown in Table 3.

## Table 3. Students placing into Calculus I

| **Placed Via** | **Total # students** | **Grade of A** | **Grade of B** | **Grade of C** | **Grade of D** | **Grade of F** | **Withdrew** |
|---|---|---|---|---|---|---|---|
| High School Course/AP | 17 | 7 | 4 | 4 | 0 | 1 | 1 |
| University Placement Exam | 4 | 1 | 2 | 0 | 0 | 0 | 1 |
| ALEKS Placement Exam | 28 | 12 | 4 | 6 | 1 | 1 | 4 |
| Transfer Credit | 3 | 0 | 2 | 0 | 0 | 0 | 1 |

In total, fifty-two students placed into Calculus I using one of the 4 placement methods. 81% of these students passed with a C or better, progressing in the math sequence. Many universities report Calculus I pass rates of 70 – 75% [12,13,14,15,16], so Marian pass rate is higher than expected. Of the seven withdrawals, five of those occurred because students changed majors and did not need calculus, so they withdrew. One of those seven repeated the course and got a B, and the final one is currently repeating the course. This data is encouraging in that the placement methods being used are appropriate for placing into Calculus I. The problem with the university placement exam is that in two years, and with ninety-four students, only four were able to place into Calculus. Those who did, however, were successful.

Finally, we have students who placed above Calculus I, either through AP scores or dual credit/transfer credit. Table 4 shows the data for these students. Neither ALEKS or the university placement exam are set up to place above Calculus, so these would be the only options. Fifteen students placed above Calculus I, and all passed the first class with a C or better. These are students with strong math backgrounds coming in, and their pass rate of 100% is expected having started at the higher level.

## Table 4. Students placing above Calculus I

| Placed Via | Total # students | Grade of A | Grade of B | Grade of C | Grade of D | Grade of F | Withdrew |
|---|---|---|---|---|---|---|---|
| High School Course/**AP** | 8 | 5 | 2 | 1 | 0 | 0 | 0 |
| Transfer Credit | 7 | 2 | 1 | 4 | 0 | 0 | 0 |

With engineering students, we were also interested if there was a correlation between placement scores and their grade in the first calculus-based physics course. This is an important course in the engineering sequence and opens up all major courses, so understanding if there was

a correlation with ALEKS scores and physics grades was important. Only thirty-seven students have completed the physics course at this point. The grades are shown below in Table 5, based on ALEKS placement scores. There was an overall 78% pass rate with a C or better, allowing continuation into other courses in the engineering sequence. Students who score 50 or above on the ALEKS exam seemed to perform at equal levels during physics. The physics courses are taught by engineering faculty, and using this table, we will have an idea of which students might struggle in that first physics course.

## Table 5. Calculus-based Physics grades based on ALEKS scores

| ALEKS score | Total # students | Grade of A | Grade of B | Grade of C | Grade of D | Grade of F | Withdrew |
|---|---|---|---|---|---|---|---|
| Below 50 | 9 | 1 | 1 | 4 | 1 | 1 | 1 |
| 50 – 70 | 14 | 6 | 3 | 2 | 1 | 0 | 2 |
| Above 70 | 14 | 7 | 3 | 2 | 0 | 1 | 1 |

**Conclusion:**

After Marian went test blind, the difficulty in math placement became more apparent. Adding an engineering school only exacerbated those problems. In trying to find an acceptable placement method, Marian discovered the ALEKS placement test, and the results of using this test are promising. Not only has it been used to place students into pre-calculus and Calculus I, the corresponding grades in these courses seem to reflect that the system is appropriate to use in our situation.

The math department and the engineering school at Marian have been working together using this data to make adjustments for future incoming freshmen classes. Since ALEKS is a more holistic approach placement testing, and since it offers students the opportunity to better prepare for mastery-based grading systems, it seems like a better option for placement testing, especially for students who are looking to place into higher level math courses. Together, we are proposing Marian adopt a two-level placement testing system. The university exam can be used to place students who only need a general education math course. For any STEM majors who need multiple or higher level math courses, ALEKS will be used for a more accurate placement. This method has been proposed to the university and is being implemented for freshmen entering in Fall 2024. Future work includes deeper analysis of the scores and correlation to demographic data of the students.

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