Exploring Direct And Corequisite Mathematics Placement At a 4-Year State University

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As enrollment in two- and four-year colleges and universities has expanded over the years, the number of students needing developmental coursework has also increased. Though the percentage of students needing support at the post-secondary level remains relatively constant, enrollment in and attention toward the creation, assessment, and administration of developmental classes across university campuses has increased substantially since the 1970's (Adelman, 1996; Boylan, 2002; Rutschow, 2019). Success rates and eventual degree attainment for students placed in postsecondary developmental pathways had traditionally been discouraging. Research shows that upwards of 50% of entering postsecondary students are placed into developmental coursework and those given a pathway of remediation are much less likely to earn a postsecondary degree (Bailey, 2009; Scott-Clayton & Rodriguez, 2012). With placement into developmental courses for low-income students occurring at much higher rates than other students, and for Black and Latino students anywhere between two to five times those for white and Asian students, remediation systematically targets our most vulnerable students (Kolodner, Racino, & Quester, 2017).

Given consistently high placement rates into developmental mathematics sequences, ensuring student success and retention through a variety of developmental mathematics reforms has become a priority (Rutschow, 2019). This study attempts to add to the understanding of the impact of various developmental reform efforts by investigating direct placement options for randomly selected students placed in the lowest developmental course at a 4-year state university in the southwest. In an effort to streamline mathematics pathways and accelerate student placement into college-level coursework, students were placed, based on their declared major, directly into their gateway mathematics course with no additional support structures or advanced, by one course, along an algebra-based mathematics pathway and provided non-content corequisite support. Student pass rates in directly placed or advanced placed courses were compared to control groups' pass rates in participating students' intended courses as well as pass rates for the general population in both the intended and direct/advanced placed courses. Findings indicate that context matters and that direct placement is a clear option for students on general mathematics pathways.

Developmental Education

Historically, community colleges and universities have used a variety of tools and measures to determine the academic preparedness of incoming students, including placement test scores, number of years of high school mathematics, high school GPA, and ACT/SAT scores. Though high school GPA is now emerging as the more reliable predictor of students' success in college-level gateway courses (Bahr, et al., 2019; Scott-Clayton, 2012), many institutions still rely on single-score placement exams or ACT/SAT test scores to determine student placement into gateway courses or into development sequences of remediation. An unfortunate outcome of over-reliance on high stakes standardized exams is that many college-ready students are often misplaced into developmental courses (Scott-Clayton, 2012). In fact, misplacement into remediation is a far more common error than misplacement into college-level courses (Scott-Clayton, Crosta, & Belfield, 2014). Some estimates show that over 30% of students are misplaced in English and almost 25% are misplaced in mathematics (Scott-Clayton, Crosta, & Belfield, 2014), with indications that more than 50% of students placed in developmental courses could earn a C or better and 25% of students could earn a B or better in the subsequent mathematics gateway course (Scott-Clayton, 2012; Scott-Clayton, Crosta, & Belfield, 2014; Scott-Clayton & Rodriquez, 2015).

As it is commonly designed, with sequences of semester-long courses that students must pass prior to being allowed to enroll in college-level gateway courses, developmental education often leaves students cycling through a sequence of material they learned in high school. The length of time it takes students assessed as needing developmental support before entering a gateway course is often a disincentive to enroll in the next course in their developmental course sequence (Vandal, 2014). In fact, research finds that the longer the developmental course sequence, the less likely it is that a student will complete the sequence and enroll in a gateway course (Vandal, 2014).

An emerging consensus in the field shows that researchers and educators alike agree that developmental education is ineffective and overwhelmingly negative for students both in terms of affect and academics. In reporting on analysis of previous research, Bailey (2009) concluded that, when controlling for equally low academic preparedness, those who take developmental courses do no better than those who enroll directly into college-level courses. This is especially true for students whose placement results lie near placement cutoff lines, thereby making the distinction between developmental and non-developmental completely arbitrary in terms of both academic preparedness and success. Some (e.g. Edgecombe, 2011) suggest that reducing the length of the developmental pathway and accelerating students into gateway courses is the best way to ensure student success.

Throughout this paper, developmental education refers to courses and instructional supports designed for students who are assessed as being academically underprepared for postsecondary education. A developmental course is one included in the educational pathway that may be taken for credit, but does not count toward a degree program, and typically involves the development of prerequisite knowledge and skills. On the other hand, a gateway course is defined as the foundation course for a program of study and includes courses that earn college credit and count toward degree requirements.

Developmental Mathematics

Because of the widespread role mathematics plays in almost every academic pathway and because mathematics is the most frequently assessed area of developmental need for post secondary students (Valentine, Kostantopoulos, & Goldrick-Rab, 2017), successful completion of mathematics developmental pathways is sometimes seen as the single largest barrier to graduation (e.g. Attewell, et al., 2006). Student success in developmental mathematics pathways often varies greatly from institution to institution and course sequence to course sequence. Chen (2016) found that 33% of all students at four-year institutions enroll in developmental mathematics courses while only 58% of those students successfully complete their developmental mathematics requirement. Just 37% of students placed into developmental mathematics courses at four-year institutions completed a gateway course in their designated subject area within two years (Complete

College America, 2012), and only 30% of students pass all of the mathematics developmental courses in which they enroll (Attewell, et al., 2006). Additionally, many students who are referred to remediation never sign up for or fail to complete their remediation sequence (Bailey, 2009). In short, developmental pathways in mathematics often fail to move students beyond remediation into gateway courses.

Alternative Placement Models

Given the many potential drawbacks associated with developmental education, including general lack of success, decreased motivation, increased expense, social and academic stigma, and lack of direct application to students' lives (Logue, Watanabe-Rose & Douglas, 2016), many institutions and states have found success with models that accelerate student pathways into college-level coursework. Since 2012, a large number of states and institutions have implemented alternative placement models that allow students to complete developmental pathways quickly or eliminate them altogether. States like California, Texas, Florida, Tennessee, and Connecticut have passed legislation to reduce the number of students assigned to developmental course sequences, to limit the length of developmental sequences, or to provide corequisite support for students placed in developmental classes (Scott-Clayton, 2018). Though these different approaches vary in intent and enactment, they all aim to reimagine the standard prerequisite model and move students into college-level mathematics courses while promoting similar or improved levels of student success.

In a standard prerequisite model, students enroll in a developmental course to improve their mathematical skills before proceeding to a gateway course during the subsequent semester(s). Depending on how low a student places, they could spend up to an academic year or longer in a developmental sequence before moving into their gateway course. One approach to shortening such a path is to merge the sequence of developmental courses students might need into a single course that serves as a prerequisite to the needed gateway course (Hoang, et al., 2017; Rutschow & Diamond, 2015). This single truncated prerequisite merges content from multiple existing developmental courses and focuses on developing mathematical skills and understanding students will need to be successful in later coursework. Developmental compression, another approach to directly shortening a mathematics pathway, includes modifying the number of courses required to reach college-level coursework (Edgecombe, et al., 2014), often differentiating curricular pathways for science or engineering students versus those in other programs of study. This approach might skip selected developmental courses deemed irrelevant for future coursework or success in a major field of study.

Yet another model for placing students directly into their gateway course is embedded remediation. Within an embedded remediation model, there are many ways to deliver the just-in-time instruction or support that students need, including extra time and carefully timed and sequenced instructional supports (Vandal, 2017). Embedded remediation, with just-in-time instructional supports that review developmental topics just before they are needed for new content, has been shown to be especially successful for students enrolled in courses that emphasize quantitative reasoning or statistics rather than the more traditional emphasis on algebraic skills (Perez, et al., 2018). Even direct placement into college-level courses without embedded remediation has been met with some success. One study out of Florida found that, after prohibiting remediation for in-state high school graduates and requiring flexible options for out-of-state students, the number of students needing developmental support fell from 38 to 22 percent in mathematics (Hu, et al., 2016). At the same time, pass rates for mathematics gateway courses fell by 7 percentage points. Although the pass rate decline might seem dramatic, by enrolling a much larger number of students in gateway courses, the percentage of students successfully completing gateway courses rose by 4 percentage points in mathematics. Researchers' overall conclusion was that direct placement was a success, when looked at holistically, since the increased number of students enrolling in gateway courses offset the lower passing rates by producing a higher number of completers.

A final model for accelerating pathways and promoting student success is the corequisite model. In a corequisite approach, students take a supplemental support class intended to provide general academic, or sometimes content-specific, support and the required gateway course simultaneously. This model is perhaps the most widely used approach to acceleration with over 24 states or systems either allowing or mandating corequisite learning support (Ran & Lin, 2022). This approach has been shown to be successful in allowing students to enroll in credit-bearing courses while also gaining the academic support they need to be successful in those courses (e.g. Buckles, et al., 2019; Edgecombe & Bickerstaff, 2018; Logue, Douglas, & Watanabe-Rose, 2019).

A large scale study out of Tennessee found that, after requiring corequisite support for all developmental courses, the number of students in community colleges who completed a gateway mathematics course in their first year more than quadrupled from 12% to 52%, and the number of university level students receiving a passing grade in their first credit-bearing mathematics class rose substantially to 75% (Denley, 2016). Ran & Lin (2019, 2022) similarly found that students directly placed into gatekeeper courses with corequisite support were 15-18% more likely to pass than those placed into a developmental prerequisite course during their first year of school. In addition, Ran & Lin (2022) found that, when compared to peers placed directly into a college-level course without any supports, students in the corequisite course were 10 percentage points more likely to pass the subsequent mathematics class. Overall, corequisite approaches have been shown to promote student success in a variety of contexts, especially when used to support students enrolled in courses emphasizing quantitative reasoning (Kashyap & Mathew, 2017; Perez, et al., 2018) and introductory statistical concepts (Hern, 2012).

Alternative Placement at SSU

This study merges recommendations and findings from various researchers by investigating the impact of two direct placement options on student success. In order to best serve students' needs, different placement options were explored for students based on the mathematical pathway mandated by their proposed major. Students whose major included college-level coursework in quantitative reasoning or mathematics for elementary education majors were placed directly into their gateway course without additional support structures. Students whose majors required a longer algebra-based sequence were placed into the next course in their developmental sequence, along with a corequisite class that provided supplemental non-content-specific support. These varied placement approaches reflect work by previous researchers who have found differentiated acceleration options can be used successfully for students pursuing different degree pathways (e.g. Logue, et al., 2016; Perez, et al., 2018). Findings indicate that context matters and automatic placement into an algebra-based developmental course may not be the optimal default placement option for students deemed underprepared for college-level mathematics.

Context of the Study

Southwest State University (SSU) is an accredited, research intensive, medium sized public university in the southwest United States serving almost 23,000 on campus students per year. At the time of this study, students at SSU received math placement based on the highest of the following measures: ACT/SAT results, math placement test results, or number of years of high school mathematics. Students with four years of high school mathematics were automatically placed above Mathematics Pathways (MAT 100) and into Algebra for Precalculus (MAT 110), Math Foundations and Quantitative Reasoning (MAT 115), or Mathematics for Elementary Teachers (MAT 130). Students with less than four years of high school mathematics could still be placed above MAT 100 if they had sufficiently high ACT/SAT or math placement test results. The locally-designed and validated math placement test was proctored, and students could take it up to 3 times. Students became eligible for subsequent courses by successfully completing the prerequisite course, transferring

in successful completion of the prerequisite course, having sufficiently high ACT/SAT scores or math placement test results, or earning AP credit for the prerequisite course.

A mathematics placement committee at SSU has been in place for over 12 years and regularly analyzes and evaluates departmental placement protocols. Keeping student success at the forefront, but remaining cognizant of the need to get students into gateway classes as quickly as possible, the placement committee frequently evaluates the relationship between student performance in various classes and placement indicators in order to better refine and streamline placement options. This study is the result of continued efforts to streamline student pathways into courses above MAT 100.

MAT 100 is the lowest class offered at SSU. It is developmental in nature and, while it does carry elective credit, it does not fulfill any degree requirements. All students included in this study were initially placed into MAT 100 based on incoming placement information, as described above. Students were randomly selected to skip over the MAT 100 prerequisite and be directly placed into the subsequent math course (MAT 110, MAT 115, or MAT 130), as determined by the student's chosen major and associated degree pathway.

As seen below (see Figure 1), a student who placed directly, through direct or standard placement, into MAT 115 or MAT 130 was able to enroll in the appropriate gateway mathematics course immediately, eliminating the developmental course in their math pathway. In contrast, there are two developmental prerequisite courses in the sequence leading to Precalculus (MAT 120), MAT 100 and MAT 110. Thus a student who placed directly, through direct or standard placement, into MAT 110, was able to bypass the initial developmental course (MAT 100) in their math pathway, but would still need to complete MAT 110 before enrolling in their desired gateway mathematics course, MAT 120. Because of this difference, direct placement into MAT 110, MAT115, or MAT 130 represented eliminating the developmental education sequence for some students while shortening it for others, depending on the specific math pathway for their chosen major.

In order to better understand how students performed in various directly placed classes, this study investigated, where applicable, (a) the pass rates of students in directly placed classes as compared to a control group of non-directly placed students who remained in the developmental course, (b) the pass rates of students in directly placed classes as compared to students from the general population enrolled in the same class, and (c) directly placed student performance in subsequent classes as compared to students who progressed to the same subsequent class through traditional placement and performance pathways.

Course Structure

The initial developmental mathematics course and subsequent directly placed courses in this study vary in their outcomes and structure. Three of the classes are part of a larger modified mathematics emporium (MME) model adopted by the university in 2012. Classes offered in the MME are typically structured around the use of an online interactive instructional program from a large scale publishing company that utilizes instructional videos, interactive software, and a guided course notebook to deliver content instruction.

Built upon a foundation of mastery learning, a true emporium model allows students to watch videos, utilize online learning software, and work through problems at a pace suited to their own needs and abilities, reaching mastery of various topics and concepts at different times throughout the semester, independent of their peers' progress. A modified math emporium approach (or MME), like the one used at SSU, allows instructors to vary instructional components to provide a more structured format through in person classes, thereby incorporating delivery of some course materials outside of the technology-mediated instructional environment. Independent research provides mixed results on MEs. While it appears that students may perform well on final exams or other in-course measures (Cousins-Cooper et al., 2017; Wilder & Berry, 2016), the impact on student attitudes, dispositions toward mathematics, and mathematical reasoning remains unclear (Aichele et al., 2012; Webel, Krupa, & McManus, 2017).

The final class included in this study is a mathematics content course for elementary preservice teachers that is not offered in the MME and uses a traditional instructional format with two or three face-to-face meetings per week and assignments based on, and drawn from, a regular textbook. All classes included in this study mandate daily attendance and participation as part of course grades. Specifics on each of the courses are provided below.

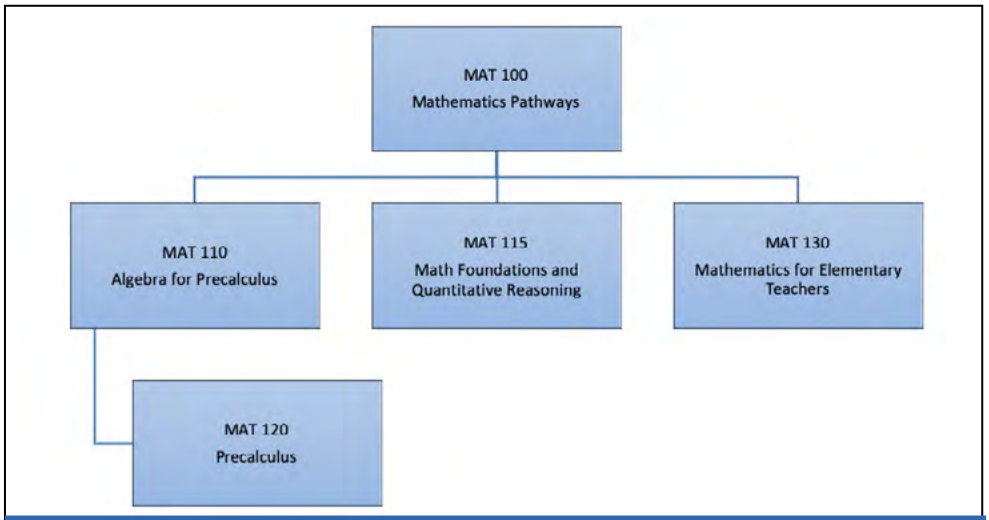

Figure 1. Progression of mathematics courses at SSU included in this study.

Mathematics Pathways (MAT 100)

MAT 100, a two-credit course offered in SSU's MME, is a developmental course designed to promote basic math skills that will help students be successful in their eventual college-level mathematics courses. MAT 100 is the lowest mathematics class at SSU and is considered a developmental course based on definitions from existing research referred to in this study. Although this course can provide students with elective credits, it does not count as a general education mathematics foundation course or count toward any degree program. This course reviews several algebra topics including the simplification of algebraic expressions, solution of algebraic equations, graphing of linear equations, and factoring of polynomials.

MAT 100 uses a widely available prominent publisher's online adaptable learning platform not used by other math courses in the MME. Unlike other courses in the MME, MAT 100 is a mastery-based course where students need to pass out of or work through over 140 algebra topics. Students meet with their instructor one day per week for 75 scheduled minutes in an MME computer lab and are then required to log at least 60 minutes weekly in individual open lab time working through content in the online content management system. Almost all time in the scheduled class meeting is spent working through online course material, with on-demand one-on-one support provided by the instructor and undergraduate peer instructors. There is little or no structured, direct instruction from the instructor to the entire class. Each section of this course has a capacity of up to 50 students, with total enrollment typically around 400 students in fall semesters and 200 students in spring semesters.

Algebra for Precalculus (MAT 110)

MAT 110 is a three-credit course that provides students with elective credits but does not serve as a general education mathematics foundation course. MAT 110 currently serves as a prerequisite for classes such as Precalculus, Introductory Statistics, and Finite Mathematics. Like MAT 100, MAT 110 is considered a developmental course based on definitions from existing research referred to in

this study. This course provides review of fundamental concepts and skills required for precalculus and covers concepts such as algebraic operations, simplifying expressions, solving equations and inequalities, and multiple representations of various linear and nonlinear functions.

In MAT 110 students have one weekly meeting in a classroom for 75 minutes in which they explore core concepts through lecture, lessons, and hands-on activities. Students also spend an additional minimum of 150 minutes in the open computer lab. Students use a widely recognized educational publisher's eBook with videos to complete notes in a workbook prior to attending their weekly class. Content modules start with a pre-test that allows the adaptive software to filter homework in order to address students' specific content needs. Each section of MAT 110 has a capacity of 72 students and is often co-taught by two graduate teaching assistants. Academic year enrollment is typically around 1600 students in fall semesters and 600 students in spring semesters.

Math Foundations and Quantitative Reasoning (MAT 115)

MAT 115, a three-credit course, fulfills the general education mathematics foundation requirement at SSU and serves as the terminal mathematics requirement for most humanities and liberal arts degrees. MAT 115 can be considered the first gateway course examined as part of this study and the primary gateway course for many majors at SSU. MAT 115 course content includes contemporary quantitative methods, especially descriptive statistics; elementary probability; limited statistical inference; financial mathematics; linear and exponential models of growth and decay; and applicable discrete models.

In addition to the one weekly meeting in a classroom for 75 minutes, students must spend an additional minimum of 75 minutes in the MME lab. Unlike MAT 100 and MAT 110, students in MAT 115 do not engage in online videos or complete packets, though there is an available eText with supplemental support videos for student use. Students in MAT 115 submit weekly online homework using an open-source homework system, take a paper-and-pencil quiz each week, and complete three large-scale projects using Excel during the semester. Each section of MAT 115 has a capacity of about 36 students and is taught by a graduate teaching assistant or departmental instructor. Academic year enrollment is typically around 850 students in fall semesters and 1100 students in spring semesters.

Mathematics for Elementary Teachers (MAT 130)

MAT 130, a three-credit course, is the only non-MME course included in this study. It is a gateway course and the first in a two-course content sequence that undergraduate elementary education majors take to fulfill the mathematics requirement of their major. MAT 130 is primarily a content course that introduces prospective elementary teachers to numeration systems, whole numbers, integers, rational numbers, decimals, real numbers, number theory, and algebra.

Students spend 150 minutes per week in a traditional classroom setting. The course emphasizes a conceptual approach to teaching and learning mathematics, so much of the time in this class is spent in small groups exploring math concepts through the use of manipulatives and student-centered investigations. Each section of MAT 130 has a capacity of 36 students and is typically taught by full time faculty from the mathematics department. Total academic year enrollment is typically around 240 students in fall semesters and 100 students in spring semesters.

Precalculus (MAT 120)

While students in this study were not directly placed into MAT 120, their performance in the course was recorded and compared to students who progressed to or placed directly into MAT 120 in the traditional manner. MAT 120 is a four-credit gateway course that fulfills the general education mathematics foundation requirement at SSU and serves as the terminal math requirement for degree programs in forestry, psychological sciences, exercise science, and construction management. It also serves as a prerequisite course for continued studies in calculus and beyond. MAT 120 covers the concept of function; graphs; absolute value, linear, polynomial, rational, exponential, logarithmic, and trigonometric functions; systems of equations; and analytic geometry.

MAT 120 is similar to MAT 110 in that it is run through SSU's MME and utilizes an online learning software program with videos and a note-taking workbook. The class has two 50-minute face-to-face class sessions per week in a classroom with their instructor. Like other MME classes, students enrolled in MAT 120 spend an additional minimum of 200 minutes in the MME lab working through course material with embedded software supports, module pre-tests, and unlimited attempts on homework. Each individual section of MAT 120 has a capacity of 72 students and is typically taught by two graduate teaching assistants. Total academic year enrollment is typically around 1800 students, split relatively evenly between fall and spring semesters.

Methods

This study focuses on student outcomes as part of a pilot study investigating the impact of directly placing students from an elective developmental basic skills course into the subsequent required mathematics course based on a student's intended major and course of study. One of the directly placed courses included supplemental corequisite support while the others did not. Random samples of MAT 100-placed but 110-, 115-, or 130-bound students were electronically generated during late spring 2018. One sample for each course served as a control group and one sample for each course served as the potential treatment group. During orientation and registration, students chosen for the treatment group were informed of their selection in the pilot program and given the option to remain in MAT 100 or take the indicated direct placed course. Associated risks of direct placement (e.g. potential for failure commensurate with MAT 100 and/or the directly placed course) were communicated to students. Very few students opted out of direct placement.

For students directly placed into MAT 110, the required corequisite class (MAT 199) met face-to-face in an MME classroom once a week for 50 minutes. The class was taught by upper division undergraduate peer mathematics teaching assistants from the MME who had received training in mathematics tutoring and academic support. These peer TA's met weekly with the course coordinator for MAT 110 in order to plan each week's topic/focus and to remain flexible in responding to students' needs. Weekly topics followed suggestions by researchers (e.g. Adams, et al., 2009) in that academic adjustment and achievement of underprepared students can be improved by providing instruction on academic skills, advising, counseling, and comprehensive support services. In the case of SSU, MAT 199 included suggestions for success as a first-year student such as regular attendance in all classes, completing required homework assignments, attending instructor office hours, finding a social and academic balance, and accessing on-campus resources for ensured success while at the university. MAT 199 did not specifically include any direct content instruction, though students were encouraged to ask questions from homework, notes, videos, or lab time during class time. In keeping with additional recommendations for corequisite course design, MAT 199 sections included small class sizes (less than 20) and were heterogeneously grouped (Adams, et al., 2009).

Student success in each of the courses as part of this study is described as "pass rate" and includes the percent of students who earned an A, B, or C as an overall course grade. The exclusion of D's as part of the pass rate reflects the university's emphasis on analyzing student success in undergraduate courses as measured by ABC rates versus DFW (D, F, or withdrawal) rates. Although using only final course grades does not provide an accurate or detailed picture of the many factors that influence student success, it does provide a broad indication of student achievement across courses.

Data Analysis

Cumulative pass rates, as determined by the percentage of students who earned an A, B, or C[1] as an overall course grade during Fall 2018 and Spring 2019 were used as the primary measure of performance in this study.

[1] At SSU, an A indicates an overall grade percentage of 90-100%, a B indicates 80-90%, and a C indicates 70-79%

Where applicable, students' pass rates in a subsequent mathematics course were also calculated. Overall passing percentages for the entire population of students enrolled in the intended course (MAT 100) and the directly placed course (i.e. MAT 110, 115 or 130) were calculated to establish a base-line pass rate for all students enrolled in each class during the semester indicated. Pass rates for control and treatment groups were also calculated. Directly placed students were also tracked as they progressed to MAT 120.

Students were randomly assigned to treatment (directly placed) and control (left in the developmental course) groups from the same pool of incoming freshmen in either STEM, non-STEM, or elementary education majors. All students selected for the study had originally placed in the developmental mathematics course MAT 100. This process allowed researchers to compare the pass rate for an indicated directly placed group of students with non-directly placed students in the lower developmental class and in the general population of the directly placed class. Significance of findings was determined by tests of a difference in proportions between stated subgroup members and non-subgroup members assuming an equality of proportions. The p-values listed represent the probability of the observed difference in the percentages if, in fact, the two percentages are equal. Conventionally, a difference is deemed significant if the p-value is less than 0.05.

It should be noted that findings were not differentiated for various student populations based on gender, ethnicity, or other subgroup-specific categories. This was intentional in that recommendations and findings were sought that could be applied across all student populations as part of continued placement protocols at SSU. Randomization of students selected to be part of the direct and advanced placed groups ensured broader applicability of findings to the rest of the student population at SSU.

Results

MAT 110 direct placement

Students considered for this part of the study were incoming freshmen during Fall 2018 enrolling in their first mathematics class at SSU. They placed into MAT 100 because they entered SSU with fewer than 4 years of high school mathematics and did not choose or were unable to place higher based on ACT/SAT or placement test results. Students in this group stated an intention to pursue a major in a STEM field necessitating a final mathematics requirement of MAT 120 or above. A total of 160 students were randomly selected to participate in this study. Students were then randomly assigned into two groups: a treatment group was given the opportunity to be directly placed into MAT 110 along with a corequisite one-credit course designed to assist students in being successful in a college course and a control group who were tracked in MAT 100 but not given the option to enroll in MAT 110.

	total	ABC	DFW
MAT 110 directly placed F18	n=86	64.0%	36.0%
MAT 110 F18 overall	n=1830	70.9%	29.1%
MAT 100 F18 (MAT 110 control group)	n=74	85.1%	14.9%
MAT 100 F18 population	n=354	79.7%	20.3%
MAT 100 F18 control to MAT 110 Sp 19	n=41	43.9%	56.1%
MAT 110 Sp19 overall	n=633	52.0%	48.0%
MAT 110 directly placed F18, to MAT 120 Sp19	n=33	63.6%	36.4%
MAT 100 F18 (control) to MAT 110 Sp19 to MAT 120 F19	n=9	44.4%	55.6%
MAT 120 Sp19 overall	n=927	72.2%	27.8%

Table 1. Performance of MAT 100 control and directly placed students in MAT 110 and MAT 120

Historically, the general pass rates for MAT 110 vary widely between the spring and fall semesters. Since moving into the MME structure, the average fall pass rate for MAT 110 has been around 70% while the average spring pass rate has been around 53%.

When looking at performance of randomly selected directly placed students (treatment) as compared to randomly selected non-directly placed students (control) during Fall 2018 (see Table 1) we found that directly placed students had less success in the directly placed class (MAT 110) than non-directly placed students had in the intended class (MAT 100). Differences in student achievement were statistically significant with directly placed students attaining a 64% pass rate and non-directly placed students attaining an 85% pass rate ($p = .0036$). Traditionally placed MAT 110 students attained a 70.9% pass rate and outperformed directly placed MAT 110 by a little over 6% during Fall 2018. This difference, though, was not statistically significant ($p = .084$).

Students who remained in MAT 100 for Fall 2018 were also tracked to determine their performance in MAT 110 during Spring 2019. For those who remained in MAT 100 during Fall 2018 and advanced into MAT 110 in Spring 2019, their performance significantly lagged behind those that were directly placed directly in MAT 110 in Fall 2019. The pass rate for the directly placed Fall 2018 students was 64% while the pass rate for MAT 110 students in Spring 2019 for traditionally advanced students was 44% ($p = .067$). This difference is not statistically significant but still notable.

Students who were directly placed into MAT 110 for Fall 2018 were also tracked to determine their performance in MAT 120 during Spring 2019, where their performance lagged behind the general population of MAT 120 students during Spring 2019. The pass rate in MAT 120 for initially directly placed MAT 110 students was 64% while students in the general MAT 120 population passed at a rate of 72%. Incidentally, the pass rate for students in the initial control group (i.e. randomly chosen MAT 100 students not selected for direct placement into MAT 110) in MAT 110 during Spring 2019 was 44%. Unfortunately, sample sizes for both of these comparisons are too small to draw conclusions or determine significance of these results. Under the MME structure, the average pass rate for MAT 120 hovers around 71% regardless of the semester.

It should be noted that direct placement into MAT 110 was attempted again during Fall 2019 with revisions to the MAT 199 corequisite course. Rather than offering students corequisite support in study skills and other facets of being successful as a college freshman, the corequisite was designed to deliver weekly content-based remediation in concepts and content known to instructors to be difficult for students in MAT 110. This just-in-time instruction was delivered in the class prior to that content/topic being addressed in class lecture and software materials (meaning, Tuesday students received this supplemental instruction on Thursday of the previous week and Thursday students received this supplemental instruction on the Tuesday of that same week). Initial results indicated that student performance in the treatment group was almost 20% lower than the general population of students taking MAT 110 that same semester and almost 30% lower than the general population of students taking MAT 100 that same semester. Although these findings point to inconsistencies regarding the impact of corequisite enrollment and highlight a need for further study with respect to the content of corequisite coursework in this context, the number of participants in both the control and treatment groups were too small to draw any meaningful conclusions (n=61 and n=38 respectively). With disruptions to Spring 2020 classes due to the COVID-19 outbreak, tracking these students' performance in MAT 120 was not done.

MAT 115 direct placement

Students considered for the MAT 115 portion of this study were incoming freshmen during Fall 2018 enrolling in their first mathematics class at SSU. They placed into MAT 100 because they entered SSU with fewer than 4 years of high school mathematics and did not choose or were unable to place higher based on ACT/SAT or placement test results. Students in this group are non-STEM majors and non-elementary education majors. MAT 115 was their only mathematics requirement for a degree in their chosen field. All students who placed into MAT 100

	Total	ABC	DFW
MAT 115 directly placed F18	n=254	89.4%	10.6%
MAT 115 F18 overall	n=754	81.7%	18.3%
MAT 115 control group in MAT 100 F18	n=136	85.3%	14.7%
MAT 100 F18 overall	n=354	79.7%	20.3%
MAT 100 F18 control to MAT 115 Sp 19	n=52	53.8%	46.2%
MAT 115 Sp 19 overall	n=1160	74.8%	25.2%

Table 2. Performance of MAT 100 control and directly placed students in MAT 115

but who would eventually need to take MAT 115 (n=390) were randomly assigned into two groups: a treatment group who were offered to be directly placed into MAT 115 with no corequisite or supplemental support and a control group who remained in their MAT 100-placed course.

Historically, average pass rates for MAT 115 have varied significantly from semester to semester being recently as low as 70% in Fall 2019 and as high as 82% in Fall 2018. An overall average pass rate for MAT 115 since adopting the MME structure is around 78%.

When looking at performance of randomly selected directly placed students (treatment) as compared to randomly selected non-directly placed students (control) (see Table 2) we find that directly placed students had more success in the directly placed class (MAT 115) than non-directly placed students had in the intended class (MAT 100). Though the difference in pass rates was not statistically significant ($p = .146$), students in both groups passed at very high rates with directly placed MAT 115 students passing at a rate of 89% and control students remaining in MAT 100 passing at a rate of 85%.

Students who remained in MAT 100 for Fall 2018 were also tracked to determine their performance in MAT 115 during Spring 2019. For those in the control group who remained in MAT 100 for Fall 2018 and continued to take MAT 115 during Spring 2019, their performance significantly lagged behind those in who directly placed directly into MAT 115. Pass rates for directly placed students were 89% and pass rates for students who advanced into MAT 115 from MAT 100 were 54% ($p < .001$).

MAT 130 direct placement

Students considered for the MAT 130 portion of this study were incoming freshmen during Fall 2018 enrolling in their first mathematics class at SSU. They placed into MAT 100 because they entered SSU with fewer than 4 years of high school mathematics and did not choose or were unable to place higher based on ACT/SAT or placement test results. Students in this group are elementary education majors taking the first of a two-course mathematics content sequence. All students who placed into MAT 100 but who would eventually need to take MAT 130 (n=93) were given the option to place directly into MAT 130. A total of 89 students chose the direct placement option and 4 students chose to stay in MAT 100.

Historically the pass rates for this class are seasonally linked with approximately 80% of students passing during spring semesters and 90% passing during fall semesters.

When looking at performance of all directly placed students in MAT 130 (treatment), we see that the 89.9% pass rate for directly placed students matches the average fall pass rate for students in the general population enrolled in this course. It should also be noted that 100% of students who remained in MAT 100 during Fall 2019 (n=4) passed. Though this difference is statistically significant ($p = .001$), the sample sizes for this study do not allow for an effective statistical test or any meaningful conclusions. The number of those who passed MAT 100 during Fall 2018 and advanced into MAT 130 during Spring 2019 is similarly too small to draw any meaningful conclusions.

Discussion

This study was designed to investigate how students placed into SSU's lowest developmental mathematics course would do if directly placed into a quantitative reasoning or mathematics content course for elementary teachers without any instructional support or into a college-level algebra course with supplemental corequisite support. The impetus for this study was to explore alternative placement options to expedite students' mathematical pathways and entry into gateway mathematics courses. Interestingly enough, this study demonstrates that context and content matter.

For students directly placed into MAT 110, findings were mixed and insufficiently clear to draw any notable conclusions about the benefits of direct placement. MAT 110 directly placed students did not do as well as MAT 100 students in Fall 2018 and did slightly less well than the general MAT 110 population during that same semester. Control students who advanced from MAT 100 to MAT 110 in the spring passed at significantly lower rates than those directly directly placed into MAT 110 in the fall, but fall versus spring pass rates in MAT 110 vary significantly so it seems uninformative to directly compare the treatment group's pass rate from Fall 2018 to the control group's pass rate from Spring 2019. Additionally, longer term success might be hindered by direct placement, as MAT 110 directly placed students from Fall 2018 passed MAT 120 in Spring 2019 at slightly lower rates than the general MAT 120 Spring 2019 population.

One conclusion that we might be able to draw from this data is that students who follow the traditional mathematical pathway of MAT 100 in the fall and MAT 110 in the spring are somehow different from those who place directly into MAT 110 upon entry at SSU. As previously mentioned the average pass rate of MAT 110 in the fall is 70% while in the spring it is closer to 53%. Matz and Tunstall (2019) drew similar conclusions when they investigated the impact of embedded remediation in quantitative literacy and college algebra courses. "These results suggest that a student's timing in taking university-required mathematics coursework may be just as important, if not more so," (Matz & Tunstall, 2019, p. 20) as alternatives to developmental math. This suggests that further research is needed with our students and others to determine not only the impact of direct placement and corequisite support, but also the timing of course offerings and student pathways.

It is also worth noting that there was some indication that students might not have done as well in directly placed MAT 110 when the corequisite course, MAT 199, focused on delivering just-in-time content instruction. This possibly contradictory finding is not new. Matz & Tunstall (2019) found that the design and implementation of the corequisite might matter more than the content of the corequisite. What appeared to have mattered most to students in their research was "...forms of academic capital that serve[d] students in a variety of university contexts, not just in mathematics courses," (Matz & Tunstall, 2019, p. 21). While this finding is not universal, it certainly does indicate a need to further explore the impact of the scope and sequence of the corequisite course when using a corequisite structure to support direct placement of students into gateway courses.

Findings for directly placed MAT 115 and 130 students were more positive. MAT 115 directly placed students did better than both MAT 100 students and the general population of MAT 115 students in Fall 2018. Control students

Fall 2018	Total	ABC	DFW
MAT 130 directly placed F18	n=89	89.9%	10.1%
Entire MAT 130 F18	n=249	90.4%	9.6%

Table 3. Performance of MAT 100 control and directly placed students in MAT 130

who advanced from MAT 100 in the fall to MAT 115 in the spring passed MAT 115 at significantly lower rates than the general population's pass rate and than those directly placed into MAT 115 the previous fall. As with MAT 110, there is a difference in average pass rates for MAT 115 in the fall (82%) versus the spring (70%), so additional research into the timing of alternatives and student enrollment needs further investigation. Having said that, the statistically significant improvement in student performance when directly placed in MAT 115 mirrors findings from researchers who have found "...students assessed as needing elementary algebra do not first need to pass that course to pass a college-level quantitative course to be successful in college," (Logue, et al., 2016, p. 592). In this context, the prerequisite algebraic knowledge taught in MAT 100 really has no direct connection to the mathematics addressed in a course like MAT 115. Because a lot of placement tests assess students on their previous knowledge of algebra, regardless of their intended major, students are often labeled not ready for an algebra sequence when they may very well be ready for a different pathway. Building on this idea, several studies have found that direct placement, regardless of perceived preparedness, into quantitative literacy and applied introductory statistics courses might be viable alternative placement options for students pursuing non-STEM degrees (Hern, 2010; Kashyap & Mathew, 2017; Perez, et al., 2018).

MAT 130 directly placed students did just as well as or better than the general population of students in both fall and spring semesters of MAT 130. The very nature of the content of this course, with its focus on student-centered exploration and application of rational numbers and operations and modeling, lends itself well to closing any gaps in understanding students may have upon entering the university. This seems to be an obvious case where an expedited mathematical pathway with automatic placement into this gateway course benefits students.

There are some obvious limitations to this study that hinder widespread applicability of findings. First, this study presents aggregate data and does not take into account factors that might influence student performance in their initially placed or directly placed class. Indicators such as placement scores being near cutoff lines, exact nature of courses taken in high school, or inequities among various student groups were not taken into account. However, random selection of participating students into control groups and directly placed treatment groups was used to mitigate some of these potential biases. Second, the fact that some courses are taught by full time faculty while others are taught by graduate teaching assistants most definitely contributes to variations in the student learning experience and may contribute to variations in student success rates. Having said that, comparing student success rates across all sections of any given course offering mediates this difference as a significant contributing factor. Additionally, the sample size for some of these findings may limit widespread applicability, especially when looking at long term impacts of direct placement. Finally, the structure of SSU's developmental and initial gateway courses, especially those housed within the MME, is quite different than what may be offered at other universities. It is difficult to separate the effectiveness of the specific models used in this study from other institutional contexts that might have impacted student success. And, although it is difficult to generalize findings from this study to other corequisite or acceleration models because of the specific nature of our courses and institutional context, "...understanding the full scope of the variation and assessing effectiveness across a range of models is important to the representativeness of findings," (Daugherty, et al., 2018, p. 20).

Conclusion

General consensus among community colleges, four-year universities, state legislatures, and researchers is emerging that students who are underprepared for college-level academic work should be given accelerated routes into programs of study and that enrollment in gateway courses should be the default placement for many more students. This study has attempted to support these recommendations by investigating two placement options and accelerated pathways for students placed into the lowest, non-credit bearing course at SSU. Like other universities, SSU relies on a traditional developmental sequence that emphasizes algebra and calculus prerequisites to the detriment of students who might benefit from additional pathway options tailored to their major program of study. In this case, students who only needed the Math Foundations and Quantitative Reasoning or Mathematics for Elementary Teachers class were better served by placing directly into the needed gateway class rather than the developmental Mathematics Pathways class. These students benefited from a more efficient pathway and many were allowed to finish their graduation requirement within their first semester or year at college. Students who needed to continue into Precalculus and beyond were better served in terms of pass rates in their first course and in the subsequent course, at least in the short term, by staying in the developmental Mathematics Pathways course.

Despite the rapid expansion of developmental mathematics reform, research is still needed to better understand the impact of various efforts and models on student outcomes (Rutschow, 2019). As Matz and Tunstall (2019) point out, "numerous pathways to and through college mathematics exist, and it is imperative that, collectively, we continuously redesign courses, collect data, and analyze student outcomes so as to inform the best strategies in our contexts, support student learning, and optimally mitigate costs for students as well as institutions," (p. 22). The biggest takeaway from this study is that context matters. Developmental education, with its one-size-fits-all emphasis on an algebra-based mathematical pathway, is too narrowly defined and may not directly align with the programs of study many students pursue. The content focus of a developmental course, a directly placed course, and a corequisite course, along with the timing of course offerings, all impact student success in directly placed courses and eventual progression through a program of study. Because the developmental course at the center of this study, MAT 100, includes a heavy emphasis on pre-algebra content and skills, it is not surprising that it plays a larger role in influencing student success in the precalculus sequence rather than the non-algebra-based terminal quantitative reasoning course or the mathematics content course for elementary teachers. Although our findings do not necessarily point to the fact that MAT 100 coursework helps students succeed at higher rates in MAT 110 or MAT 120, the findings certainly do not give us enough ammunition to say that MAT 100 does not contribute to success.

Findings from this study and others (e.g. Logue, et al., 2019; Kashyap & Mathew, 2017; Perez, et al., 2018) suggest that automatic placement into an algebra-based developmental course may not serve all students' needs. In fact, better understanding the mathematical content needs of non-algebra-based programs of study might allow students to be placed into gateway courses, with or without instructional supports, that more closely align with the needs of their major.

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