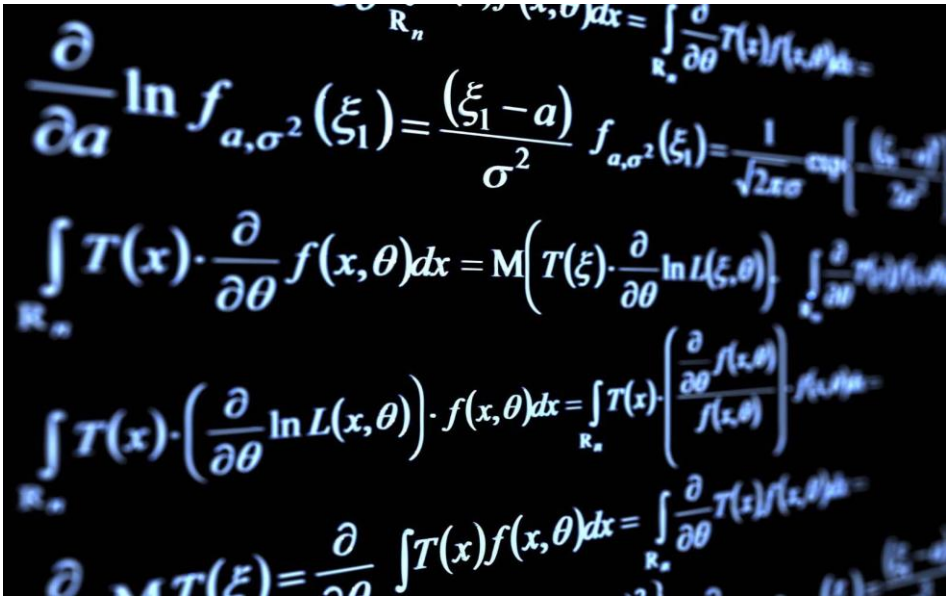

WCU STEM MATH PATHWAYS TASK FORCE REPORT

September 2018

Research and Recommendations

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WCU STEM Math Pathways Task Force Charge February 12, 2018

The STEM Math Pathways Task Force has been convened to address the problem of placement and preparation of students whose academic career goals include MATH 153 Calculus I.

Issues leading to the formation of the Task Force

- We have an increasing number of students choosing programs that require Calculus I and beyond, such as Pre-CS and Engineering. This student population has a large variance in preparedness for college-level mathematics coursework, with a wide range in mathematical skills, study habits, and motivation.
- We have recently revised our placement strategy for the courses MATH 133/146/153 to include an indicator of college preparedness (unweighted HS GPA) as well as an indicator of general mathematical achievement (ACT MATH).
- The new math placement strategy identifies a cohort of students who are underprepared even for MATH 130. (This is supported by anecdotal evidence from the instructors.) We have no current remediation options for those not ready for MATH 130.
- The content syllabi for MATH 130 and MATH 146 have significant overlap.
- Transfer articulation with the NCCCS is flawed. MATH 146 is equivalent to MAT 171/172 but we have no equivalent for MATH 130. (NCCCS removed college algebra from its catalog.) Students who completed only MAT 171 either have to jump to calculus without a sufficient background in trigonometry or repeat MAT 171 material as half of MATH 146.
- MATH 130 currently plays a different role as a terminal course for a degree program. In addition, some students elect to take MATH 130 for the Liberal Studies requirement, when they may be better suited for MATH 101 or MATH 170.
- MATH 130 may not be meeting the C2 LS goals.
- Current trends in undergraduate mathematics education are moving away from remediation and a dedicated college algebra course and toward a “pathways” model in which students have different paths or different corequisite courses to take based upon their entry point.
- Math faculty with interests in MATH 130/146/153 courses have expressed interest in revising MATH 130 and or MATH 146 to improve preparedness and student success. They are in general supportive of a pathways model.

Suggested areas to investigate

- Review literature on pathways toward calculus. Include recommendations from professional organizations such as MAA/CUMP, AMATYC, NCMATYC, NCTM/NCCTM.
- Examine models from other institutions (e.g., UNC System, peer institutions, NCCCS, Tennessee and Texas community colleges, the Charles A. Dana Center at the University of Texas).
- Examine UNC System articulations with NCCCS.
- Find data on learning outcomes and future mathematical pathway success.
- Identify needs of key stakeholders for MATH 130/146 at WCU.

Outcomes

- Report processes and findings to the Department Head of MCS by September 30, 2018.
- Make recommendations for the next stage of this study of mathematics pathways.

WCU STEM MATH PATHWAYS TASK FORCE REPORT

RESEARCH AND RECOMMENDATIONS

INTRODUCTION

In spring 2018, as the Charge on the previous page specifies, Western Carolina University's Mathematics and Computer Science Department examined the status of student success in introductory STEM mathematics courses, such as College Algebra and Precalculus, with the intent of providing students with better targeted options depending on their academic path. The introductory mathematics courses currently offered at WCU include a liberal studies course Mathematical Concepts focused on quantitative literacy consisting of selected topics of interest for students who only need to complete one mathematics course, College Algebra which serves as a preparatory class for Precalculus, Applied Statistics which seems better suited for many students who take College Algebra, and one Precalculus option which repeats a significant part of College Algebra before delving into additional topics.

The Charge provides the overall Task Force goal "to address the problem of placement and preparation of students whose academic career goals include MATH 153 Calculus I". This involves discussing proper placement of students, limiting conflicting transfers from other institutions such as Community Colleges, and finding ways to address the increasing gaps of mathematical knowledge in our STEM math student population.

Our Task Force met monthly from February to September 2018. In addition to conducting extensive research on various programs that have experimented with remediation and restructured STEM track classes, we also interviewed peer institutions to learn about their attempts at addressing similar issues. Several possible models came to the forefront. We hope our recommendations for WCU can help move forward and support students' success. This report is organized as follows:

PROBLEMS AND GOALS

The Math STEM Pathways Task Force has identified and focused our efforts on the following six Mathematics and Computer Science Departmental problems identified in the Charge presented in February of 2018. These problems will be referenced in the Recommendations Section of this report by number. We also developed five goals for our taskforce recommendations.

P1: Variance in students' preparedness for college-level mathematics

P2: No formal mathematics remediation options for underprepared students

P3: Lack of alignment with NC Community College System mathematics track

P4: Increasing number of underprepared STEM majors in need of Precalculus or Calculus

P5: Duplication of content in College Algebra and Precalculus

P6: Use of College Algebra as a terminal Liberal Studies course when other courses are better-suited to serve this purpose

G1: Lessen DFW rates in STEM track mathematics courses without compromising necessary content

G2: Prepare students more effectively for the mathematical topics currently in Precalculus and Calculus while still making it feasible for students to complete mathematics requirements for STEM majors within 4 years

G3: Align more meaningfully with Community College classes to eliminate barriers for transfer students

G4: Place STEM students in the most appropriate courses according to their major program needs given their preparedness level

G5: Continue to collaborate with the Mathematics Tutoring Center to address the remediation needs of mathematics students

The above-stated goals and recommendations that follow were considered in relationship to the Mathematics and Computer Science Department's Mission that focuses on the importance of teaching and the learning process: "the most significant of the Department's activities are the teaching and learning processes that take place between students and faculty in classrooms and field locations (e.g., student teaching)" (Department of Mathematics and Computer Science, 2018, Mission section, para. 2). The Task Force's goals regarding community college alignment also directly addresses the WCU Strategic Plan "2020 Vision: Focusing on Our Future" Goal 1.5 of the Academic Excellence Directive which seeks to "eliminate barriers to student access through coordinated endeavors with Birth-12 (B-12) and community college partners." (Western Carolina University, 2018a) Other ways in which our future work can align with the 2020 Vision will be shared in the Future Directions section of the report.

RESEARCH AND FINDINGS

Definitions and Promising Practices

Two ubiquitous terms in the language surrounding many institutions' efforts to increase retention and realign STEM tracks are "Supplemental Instruction" (SI), and "Corequisites." These refer to two models of additional classroom support for students.

Supplemental Instruction (SI)

Supplemental Instruction often refers to a formally developed structure that was developed by Dr. Deanna Martin at the University of Missouri at Kansas City, in 1973. While many institutions that this Task Force interviewed adopted some form of the model developed in Kansas City that they termed "Supplemental Instruction," we found the SI models to be myriad in form and implementation from one campus to the next.

Below is the definition of SI found on the UMKC website.

> *"Supplemental Instruction (SI) is an academic support model that utilizes peer-assisted study sessions. The SI program provides regularly scheduled review sessions on course materials outside the classroom. SI study sessions are informal seminars in which students compare notes, discuss readings, predict test items and develop tools for effective organization. The SI program targets traditionally difficult courses at the undergraduate, graduate and professional school levels.*
>
> *SI is a free service offered to all students in a targeted course. SI is a non-remedial approach to learning as the program targets high-risk courses rather than high-risk*

> *students. Participation is voluntary, but all students are encouraged to attend SI sessions. Students with varying levels of academic preparedness participate in and benefit from SI. This program was developed at UMKC in 1973 and is used in hundreds of colleges and universities around the world."* (University of Missouri-Kansas City, 2018)

It is interesting to note that in the strict definition of SI at UMKC, attendance by students is voluntary. SI sessions do not target any specific students, but they do target "historically difficult courses." SI sessions are facilitated by SI Leaders (SIL). SI Leaders are students who have successfully completed the course, attend the class for which they are the SIL as an embedded student, model good student behavior, and meet with the instructor of the course weekly. However, while they do regularly communicate with the SI Leader(s), instructors are not permitted to know who is or is not attending these peer-led sessions. In short, this model is unique in that it is driven mainly by students as peer-leaders. There are problems with the strict definition of SI. For example, Delaware Valley University found that because SI is voluntary, it 'self-selects' motivated students and reaches only a fraction of the students who could benefit from it (J. Yard, personal communication, May 2018).

Many institutions have adapted the SI model and have pushed that model further by making the SI sessions mandatory. Some institutions, like University of Colorado at Boulder, offer credit for these mandatory supplements to their regular classes like a lab that might traditionally be connected to a course like Chemistry or Biology. Some institutions, like Delaware Valley University, do not offer credit for SI, while they still make attendance mandatory.

SI courses can be offered with a variety of different structures depending on the needs of the institution. Some SI is offered once or twice per week, and most sessions last one to two hours. What the supplemental instruction covers varies. For instance, some institutions use the time not only for further instruction in the course's subject matter, but also for developing students' understanding of how they learn and how they can become successful college students. Study habits, time management, and test-taking strategies are all topics that may be explored within the SI curriculum in addition to course subject-matter. Who teaches a SI course also varies. Some institutions employ full-time faculty to lead them, while other universities employ graduate students or even undergraduate students. In short, this model allows institutions flexibility in the design of a course supplement and does not necessarily rely heavily on student employment.

Corequisites

The term "corequisite" is often used often to draw a comparison to the prerequisite model of mathematics that is common to many universities. The term corequisites suggests that, unlike prerequisites, courses may be offered concurrently either in their entirety or piecemeal to support each other. This doesn't mean that two courses such as College Algebra and Precalculus are now just simply both offered to students at the same time. Typically, if courses or parts of courses are listed as

corequisites, there is a considerable amount of thought behind the structure of these courses so that they inform and complement each other. Corequisites tend to be implemented to speed up students' exposure to college-level coursework that is required for their majors while offering ongoing support for content gaps in students' prerequisite competencies.

Many universities, including WCU, have well-defined supplemental instruction models in place. It is valuable to note though that the terms "supplemental instruction" and "corequisite" are used interchangeably in some organizations while meaning two different things in other organizations. In our study of other institutions, many universities use either or both terms frequently to describe a variety of practices where students receive additional coursework outside of the primary course meeting times. The term "Supplemental Instruction" is often used to focus attention on the practice of remediation and ongoing support and is typically defined as optional for students to participate in whereas use of the term "Corequisite" focuses attention on the practice of accelerated pathways and corequisite student participation can be mandatory. In practice, however, because these words aren't used in a universal way, understanding what practices universities engage in requires looking at the details of the programs they implement and talking with them about what they do, as opposed to just using the words they use to categorize the programs. For the purposes of this report we will use these two terms somewhat interchangeably, but we will use "corequisite" exclusively when the extra course instruction is mandatory and credit-bearing for two linked classes.

Promising Practices

Our task force has identified some promising practices for the STEM track mathematics courses which will be discussed in subsequent sections. Our basis for considering these practices as "promising" comes from our review of relevant literature supplied by the Dana Center at Austin, TX and the UNC Math Pathways Task Force, our own searches for information from other institutions and policy documents, and our interviews conducted with various universities.

We have identified the following practices as promising for our introductory STEM mathematics courses:

- Just-In-Time Remediation

Just-In-Time Remediation means that students are offered remediation to support the content in their primary course when they need it, i.e. "just-in-time". Thus, remediation takes place during the course itself, rather than isolated in a prerequisite course. Just-in-time remediation from an SI or corequisite model can also provide students with the rationale, motivation, and platform for learning the prerequisite coursework (Hern & Brezina, 2016). When executed effectively, just-in-time remediation can accelerate the process by which students enter college credit-level courses and enter mathematics courses necessary for their majors.

- Accelerated Pathways

Accelerated coursework may seem counterintuitive in a mathematics teaching and learning culture that promotes the idea that students who demonstrate difficulty learning the material should slow down, take extra time for concepts to "sink in", and master the content before moving on to another course. Many studies, however, suggest that offering coursework that short-cuts long paths to required mathematics courses is more successful for student learning, often dramatically so (e.g. Complete College America, 2018; California Acceleration Project, 2018). While students' time to complete requirements is shortened, students may experience more intense mathematical experiences that require more weekly contact hours with mathematics than their typical courses. This can't take place however, if students don't have meaningful experiences with SI or corequisite learning opportunities to fill in the gaps. Encouraging underprepared students to seek remediation concurrently with higher-level courses affords them quicker entry in major coursework.

Professional Calls to Action

As is often the case in mathematics and education, there is no shortage of professional opinions regarding the directions that undergraduate mathematics programs should take. In recent years, many of the largest professional organization have teamed up to unite their voices on major policies and directions for the near future. In 2014 the Mathematical Association of American (MAA), the American Mathematical Society (AMS), the American Statistical Association (ASA), the Society for Industrial and Applied Mathematics (SIAM), and the American Mathematical Association of Two-Year Colleges (AMATYC) joined forces to produce the guiding document *A Common Vision: For Undergraduate Mathematical Sciences Programs in 2025*. This document articulated among other things the concept of Mathematics Pathways for undergraduate mathematics, stated that "the status quo is unacceptable" (Saxe & Braddy, 2015, p.1) and called for universities to "begin to think in terms of a broader range of entry-level courses and pathways into and through curricula for all students, including mathematics and other STEM majors as well as non-STEM majors". (Saxe & Braddy, 2015, p. 13).

Collaborations such as AMATYC partnering with the MAA's CUPM (Committee on Undergraduate Programs in Mathematics) subcommittee CRAFTY (Curriculum Renewal Across the First Two Years) have led to major contributions and reconceptualizing of gateway courses in the 2015 CUPM Curriculum Guide to Majors in the Mathematical Sciences. This document referenced supplemental instruction models for recognizing that different students require different strategies while also articulating that mathematics courses are one of the biggest contributors to students' inability to graduate (Zorn, 2015).

Currently there is a significant and growing body of documents that call for undergraduate mathematics programs to revise, re-envision, and reinvest in new models for all students' success in mathematics courses including major themes of Math Pathways and support for students who are underprepared. Indeed, many institutions are experimenting with new models and there is an

accompanying sizable amount of literature on the successes and setbacks that universities have experienced as they go through growing pains of implementing a new model for undergraduate mathematics. Some institutions have begun publishing research on their results which is helpful to support our intuition about and anecdotal references to successful types of restructured STEM track mathematics and remediation. Some of these are referred to later in this document.

Peer Institutions Findings

In 2011, the UNC Board of Governors identified the following institutions as peer institutions for WCU. Based on this identification, we contacted each of these institutions and asked them for an interview. The highlighted universities responded positively to our request and we were able to arrange to conduct a semi-structured interview with 8 of the highlighted institutions – Eastern Illinois University and Winona State University both responded that they were not engaged in any of the practices that we identified as of interest, so we did not conduct follow-up interviews with them.

California State University-Fresno

California University of Pennsylvania

Central Connecticut State University

Eastern Illinois University

Kennesaw State University

Morehead State University

Murray State University

Pittsburg State University

Plymouth State University

Radford University

Saint Cloud State University

Salisbury University

Sam Houston State University

Southeast Missouri State University

SUNY College at Oswego

University of Central Missouri

Western Illinois University

Winona State University

Task Force team members divided up the schools and spoke with representatives from the mathematics departments highlighted above who have been involved with any new initiatives. Discussions focused around a) the structure of courses leading up to Calculus, b) placement requirements for these courses, c) the use of corequisite structures in some of these classes, d) creative approaches to teaching these courses, and e) what pathway (if any) is offered for non-STEM majors.

Appendix A details the course lineup for students who are heading towards Calculus along with comments about credit hours and placement at each of the universities interviewed. There are a variety of types of corequisite and supplemental instruction structures being used at many of these universities. Detailed examples of the various support structures in universities are provided in Appendix B. Overall,

corequisite models have been successful, but they are all being done in slightly different ways and in different courses.

In one of our conversations with a peer university, we learned of a potential pitfall that we need to be careful to avoid. When Kennesaw State implemented an SI model where students led voluntary sessions outside of class, their university used their best mathematics students for the job. This depleted their resources of student tutors, and now their university is not able to staff a drop-in mathematics tutoring center. While we work to provide more support for our students in classes like Precalculus at WCU, we need to be careful to also maintain our currently vibrant, flourishing Mathematics Tutoring Center which is an excellent resource for all mathematics classes.

UNC System Findings

The current state of gateway and introductory mathematics courses among the UNC campuses can be best described as "in flux". Each campus is currently participating in the system-wide UNC Mathematics Pathways Task Force and members of that task force agree that their departments could benefit from various aspects of mathematics pathways reforms, including reconceptualizing college algebra courses and corequisite/supplemental instructional models for STEM pathways. Few campuses, however, have attempted any independent reforms of their STEM mathematics curricula prior to the implementation of the task force. None of the campuses have adopted formal Pathways Models for their courses yet, but this change may come soon to the UNC system.

The Current State of College Algebra among the UNC Campuses

Most UNC campuses report difficulties in handling remediation and developmental mathematics in their courses especially as it relates to algebraic competencies. Many campuses' representatives report that their grades for college algebra courses are not what they would desire, DFW rates are high, and that current college algebra courses provide only limited preparation for subsequent courses. All campuses currently offer at least one college algebra course except UNCA. In addition, ECU, FSU, NC A&T, UNCG, and WSSU all offer multiple introductory algebra courses. Some of these courses do not count for college credit and are designed to be developmental courses. Other universities provide multiple offerings that distinguish algebra for sciences versus algebra as a terminal course for a general education requirement. Some algebra course work in these universities is offered together with basic trigonometry prior to entry into a precalculus course.

UNCA is the exception to the rule when it comes to college algebra. They haven't offered a college algebra course in many years. Their STEM track begins with a one-semester Precalculus course which is explicitly designed for those students who need to take Calculus I but aren't academically prepared to enter Calculus I outright. The prerequisite to Precalculus is two years of high school algebra. Students who have had prior college algebra coursework or trigonometry coursework at the college level may not get credit for UNCA's Precalculus course. Subsequently, students who enter Calculus I are expected

to have experience with college algebra and/or trigonometry, but no numbered prerequisite is identified. In addition, no major at UNCA requires Precalculus without Calculus I. Students who are underprepared for Precalculus are encouraged to seek online resources for additional remediation in the precalculus course. Online remediation is optional, however, and isn't uniformly administered according to Department of Mathematics Chair, Lothar (Till) Dohse (personal communication June 2018).

Corequisite and Supplemental Instruction Models among the UNC Campuses

Corequisite courses and SI in mathematics courses are relatively new phenomena and a few UNC campuses are starting to implement or pilot these instructional models in their courses. UNCC is implementing a version of an SI model for their chemistry classes that has been regarded internally as successful (C. Wayland, personal communication, June 2018). They are considering extending a form of SI in some mathematics courses. Three other campuses, UNCG, ASU, and NC A&T, are currently implementing their own versions of SI or corequisite models specifically in mathematics courses from the STEM track.

ASU has implemented a version of an SI model for the first semester Calculus I course where the SI instruction has been taught by a faculty member with additional help from graduate students. The SI is an optional one-hour course/lab that focuses on algebraic competency embedded in Calculus I. Since the SI is not required, faculty report that some students who don't select to participate in the SI could really benefit from it (K. Mawhinney, personal communication, May 2018). Students who did participate in SI reported that it helped with their confidence and proficiency in Calculus I. Many students requested additional SI in calculus topics beyond the algebraic ones.

For the first time this fall, NC A&T will offer a course called MATH 101E, Fundamentals of Algebra and Trigonometry I with Pre-College Math Enhancements. This course is designed to support students who aren't academically prepared to enter MATH 101, which is the same course without enhancements. MATH 101E will include two additional outside hours of supplemental instruction per week that will be faculty-led. Placement in the course will be determined by SAT/ACT scores or department placement test results.

UNCG offers both a two-course precalculus track and a single, accelerated precalculus course. As part of the accelerated sections, students are required to attend a one-hour per week mandatory course which is facilitated by a graduate student. Placement rubrics are used to determine if students have the background necessary to take the accelerated courses. Instructors determine how to count the one hour per week in the grade for the course. Associate Department of Mathematics and Statistics Head, Dr. Dan Yasaki claims that the additional lab can be difficult to schedule partly because it falls outside of the regular times for courses and partly because they are designed not to overlap with science lab sections since students will often have to take both types of labs (personal communication, August

2018). Yasaki also claims that students who take the one-semester precalculus course at UNCG seem to perform better in Calculus I (personal communication, August 2018). He attributes this to a couple of factors. One factor is that students who take Precalculus in accelerated sections are stronger mathematically to begin with when they enter Precalculus and the one-hour corequisite seems to remediate their gaps in understanding. Another reason is that the assignments in the one-semester precalculus course are designed to prepare students for calculus topics specifically whereas the two-semester precalculus course assignments are not as focused on preparation for Calculus I. Typically, UNCG's two-semester precalculus courses aren't taught with a corequisite model. However, they offer a hybrid online version of them where students meet as a class once a week and then are required to spend three additional hours individually at the Math Emporium where they get online instruction in the course that is supplemented by graduate student assistance.

Developments from the NC Community College System (NCCCS)

From 2012 to 2014, the NCCCS engaged in a systemic Mathematics Curriculum Improvement Plan (CIP). Part of the reform stemmed from students getting stuck in long sequences of developmental-level courses that often resulted in failing grades and the inability to advance to required courses for their degree programs. One of the benefits of studying the NCCCS developments is, unlike the newer UNC system developments, NCCCS has data-based findings from five years or more of studying their students' experiences with their reforms.

Because of the CIP, one change to their curriculum was the restructuring of Precalculus. Prior to 2013, NCCCS offered two calculus tracks, a two-semester precalculus model and an accelerated one semester precalculus course. Students could enter the one-semester precalculus if they qualified for it through placement. Approximately 16% of precalculus-bound students qualified for the one-semester course and the other 84% took the two-semester courses. NCCCS found that there were significant differences in DFW rates between the two precalculus tracks and because the DFW rates were so high for the single-semester course, they eliminated it in 2013 (Loss & Cauley, 2017).

Another recent development from NCCCS is their decision to overhaul their developmental mathematics program. NCCCS identified compelling data from Georgia, Tennessee, West Virginia, Indiana, and Colorado that suggested that moving from a 2-year prerequisite model for gateway courses to a 1-year corequisite model for the same courses, students were far more successful (Complete College America, 2018). Table 1 demonstrates the five state systems that changed from a prerequisite 2-year path to complete a gateway course to a 1-year corequisite model to complete a gateway course and the percent of students who completed the courses. NCCCS has implemented its own pilot study among 16 campuses starting this fall term.

NCCCS' corequisite model called RISE (Reinforced Instruction for Student Excellence) is projected to increase students' successful completion of Gateway courses by 79% and particularly, increase minority

students' success in Gateway courses 240% (Loss, 2018). These results are based on national surveys of institutions that have implemented the restructured courses. Their pilot study consists of offering their first course of precalculus with additional hours of a-la-carte corequisite developmental mathematics that could total up to 9 hours of mathematics during the semester.

TABLE 1

State – Mathematics	Prerequisite Model 2-yr Gateway Success	Corequisite Model 1-yr Gateway Success
Georgia	20%	63%
Tennessee	12%	61%
West Virginia	14%	62%
Indiana	29%	64%
Colorado	31%	64%

Note. Complete College America (2018)

Promising Models Beyond Our Neighbors and Peers

The WCU STEM Math Task Force was charged with investigating literature on models for the STEM introductory mathematics courses, considering how comparative peers and UNC peers are dealing with many of the problems related to college algebra, and recommending a curriculum revision. To that end, we began to investigate published literature from other universities who had addressed some of the issues with their mathematics courses. The universities selected had been previously identified from UNC Task Articles and/or a search via the web. Further, to be as thorough as possible, follow-up phone interviews were conducted with these universities. The results and findings from a few of these universities has been summarized below.

AUSTIN PEAY STATE UNIVERSITY

Under the guidance of Provost Tristan Denley, the university introduced a developmental redesign of their college algebra courses. Elementary and Intermediate Algebra were replaced with 'enhanced' versions of College Algebra and Statistics, which included computer-based modules designed to meet the skill deficiencies of each student. The results of their developmental redesign have been

noteworthy. Instructional costs have been reduced by 52%. Completion rates rose from 33% to 74% in College Algebra and completion rates rose from 23% to 52% in Statistics. Among those who completed the enhanced courses, retention rates (fall to fall) rose from 59% to 66%. (Denley, 2012)

TENNESSEE COMMUNITY COLLEGE SYSTEM

The community colleges in Tennessee have implemented a corequisite program for both mathematics and writing. In a 2014 pilot program, students across nine of the states thirteen community college campuses (total of 1,019 students) were targeted for this pilot study. These students who ordinarily would have followed the traditional prerequisite path, that is they would have been assigned to take a developmental course followed by a credit bearing math course; were instead assigned to a credit-bearing introductory course in statistics with mandatory supplemental instruction. The results were rather stunning. The pass rate of a college-level mathematics course jumped 49%, from 12% in the 2012-2013 cohort to 61% for those in the 2014-2015 pilot (Complete College America, 2018).

CALIFORNIA STATE SYSTEM

The largest four-year public university system in the United States will adopt a corequisite model for the delivery of developmental education beginning in fall 2018 highlighting that corequisite models are a growing national trend. In this approach, incoming students who have been assessed as academically underprepared are no longer placed in a series of "remedial courses" that do not count for college-level credit. Models in California place underperforming students immediately into credit-bearing classes while simultaneously providing them with rigorous just-in-time support designed to bring academic skills to the required levels (Becker, 2017).

UNIVERSITY OF COLORADO AT BOULDER

UC Boulder believed that with the ever-increasing numbers of incoming freshmen, it was essential that students receive appropriate academic advising from the beginning about which mathematics course was best suited to their individual programs of study rather than being placed into College Algebra by default. An additional concern centered on the issue of remediation. While it was true that many students needed mathematical remediation, traditional remediation had not shown them a way to begin placing students with limited academic deficiencies directly into college level courses with corequisite instruction. This understanding led the University of Colorado at Boulder to implement the following strategies. In the fall 2016 they decided that College Algebra would no longer be offered through their main campus. In the 2017/2018 academic year, they began using a predictive model to better place students into the best math courses for them. Students who failed to meet the minimum standard requirement for admission into could opt to take a proctored assessment test before the start of the fall semester. Additionally, all students were required to take a one-credit hour, two-hour face-to-face time supplemental lab each week. Combined with the four-credit hour course, the student would receive a total of 5 credit hours. During the first week of class, a student could test out of the

supplemental lab. Results from this past year of using the corequisite model for all students have not yet been determined.

DELAWARE VALLEY UNIVERSITY

Delaware Valley University believed that for its success, the version of Supplemental Instruction (SI) defined at the University of Missouri, Kansas City and stated earlier in this document had one significant limitation – participation was voluntary. Because SI is voluntary it 'self-selects' motivated students and doesn't reach many students who would benefit from it. Unfortunately, many students do not become aware of their need for SI until they are at a point in the semester when it may be too late for intervention to have a significant impact. This was the realization that led Delaware University to initiate their own version of a corequisite that mandated participation during the freshman year. Prior to implementing the mandatory corequisite, only 61 % of students enrolled in Fundamentals of Algebra (a non-credit pass/fail developmental math course) successfully completed the course. In the four years since the instruction was mandated, that number has increased by nearly 12%. (J. Yard, personal communication, May 2018)

FRAMINGHAM STATE UNIVERSITY

In the fall of 2016 Framingham State University implemented a corequisite/remediation model for one section of College Algebra. In the spring of 2017 they added an additional section of Introduction to Statistics. All students involved in this pilot were required to take a corequisite lab. This just-in-time remediation Lab met for two hours, once each week. While the pilot only involved two sections, the test results were encouraging as the DWF rates were lower than the average for 100 level math courses (Math Pathways Subcommittee of the Task Force on Transforming Developmental Math, 2017). The initial success of this corequisite model led the university to implement this Corequisite/Remediation model for all 100-level math courses in fall 2017.

UNIVERSITY OF TENNESSEE AT KNOXVILLE

The Vice Provost identified College Algebra as one of the most important courses in terms of year to year retention. This prompted the university to complete a study of their College Algebra students over the last five years, which led to a rather astonishing connection; most students who did not graduate in the last five years had not passed College Algebra according to department head Dr. Conrad Plaut (personal communication, May 2018). The ACT is currently used for placement: College Algebra (ACT 22-24), Precalculus (ACT 25-27), Calculus I (ACT 28+). Students with an ACT score below 22 are required to take a one hour 'prep-course' which focuses on study skills and how to be successful in college). In addition, three years ago the university introduced a three-week summer Math Camp, which includes intensive training in College Algebra, and 'how to be successful student'. This program has shown to be very successful, however it can currently only serve about 80 students.

CURRENT SNAPSHOT OF STEM MATH GATEWAY COURSES AT WCU

The Current STEM Math Track

For students who enter WCU in need of Calculus I (MATH 153) but are not prepared for it, WCU offers two courses, College Algebra (MATH 130) and Precalculus (MATH 146). MATH 130 is the lowest level course in this sequence designed to prepare someone for MATH 146. A student who starts in MATH 130 would subsequently take MATH 146 before advancing to MATH 153 if Calculus I was the goal. Of course, students can also place higher than MATH 130 based on SATs/ACTs, HS GPAs, and AP course scores.

Who Takes MATH 130, 146, and 153 at Western Carolina University

No current major at WCU requires students to complete MATH 130 College Algebra as an only mathematics option in their program requirements. Nursing currently requires a mathematics course at the 130 level or higher meaning that MATH 170 (Applied Statistics) could serve as an option for Nursing students. Entrepreneurship requires either MATH 130 (or another MATH that has 130 as a prerequisite), MATH 170, or QA235. Both Electrical Engineering and Engineering programs suggest 8-semester plans that begins in the first semester with MATH 153. Fifteen majors mention MATH 146 specifically in the major program requirements. The specific arrangements are listed below in Table 2.

Appendix C shows the number of students who attempted MATH 130 from the fall term in 2012 to the fall term in 2017, organized by their majors (Western Carolina University, 2018b). The table shows that only 8 majors (Social Work, Psychology, Political Science, Nursing, Forensic Science, Criminal Justice, Construction Management, and Biology) comprise nearly 50% of all students who have recently attempted MATH 130. Additionally, undeclared students account for about 10% of all students who choose to take MATH 130.

Approximately 3,675 students have taken MATH 130 between the fall term of 2012 and the fall term of 2017 (including the latter). Of those students, 81% passed MATH 130 eventually, although 34% of MATH 130 students earned an F or withdrew on their first attempt. Eight hundred seventy-five students took MATH 146 at WCU during this time and of those 875 students, 88% (776) also passed MATH 146. Of those students who took MATH 146, 383 also took MATH 153 at WCU of which 85% (329 students) passed all three courses. Less than 10% (329/3,675) of all students who take MATH 130 at WCU go on to complete MATH 153 at WCU. Approximately 24% of students who took MATH 130 go on to take MATH 146 at WCU. For the other 76% of students, MATH 130 is a terminal mathematics course unless they transfer to another institution after having taken MATH 130 at WCU. (Western Carolina University, 2018c)

TABLE 2

Major Requirement According to the 2018-2019 Course Catalog	Majors
Requires MATH 153 and recognizes students may need to take MATH 146 as a prerequisite	Mathematics, Biology, Chemistry, Computer Science, Forensic Science
Requires MATH 146 specifically	Electrical and Computer Engineering Technology (and MATH 146 is a prerequisite to ECET 231), Natural Resource Conservation & Management, Middle Grades Education (Math Concentration), Science Education, Engineering Technology, Environmental Health
Requires MATH 146 AND other mathematics	Construction Management (MATH 170), Geology (either MATH 153, 170, or 270),
MATH 146 is mentioned as one of many preferred electives	Elementary Education with MATH SAC
Either MATH 146 OR another math course is required	Environmental Science (MATH 153)

Though most students passed MATH 130, as stated previously 34% have had to repeat the course at least one time to pass it and this did not guarantee success in MATH 146 or MATH 153. Also, as earlier mentioned, no current major at WCU specifically requires completion of MATH 130 as an only choice but many majors reference MATH 146 and/or MATH 153 as required. For students who take MATH 130 and intend to continue to MATH 146 for their major requirements, they may benefit by being able to enter Precalculus as quickly as they can without compromising the remediation they may need to be successful at it.

NCCCS/WCU Articulation Agreements

The current articulation agreement WCU has with the NC Community College System (NCCCS) for mathematics is imperfect in terms of placement and matching content between NCCCS courses and MATH 130 and 146. The NCCCS offers Precalculus Algebra MATH 171 (4 credit hours) and Precalculus Trigonometry MATH 172 (4 credit hours). MATH 171 covers only the first half of WCU's Precalculus MATH 146 and does not transfer in as credit for MATH 146. It transfers in as MATH 130 (3 credit hours) and one hour of MATH 19x. Students who have taken MATH 171 in NCCCS must take MATH 146 which

repeats half the material from their MATH 171 course. If students take MATH 172 in the NCCCS system, then they receive credit for MATH 146. Thus, NCCCS students who have taken half our current precalculus course at CC only get credit for College Algebra (MATH 130). CC students who complete the second precalculus course have covered far more topics than our Precalculus students, but they only receive credit for our single precalculus course (MATH 146).

Placement and Remediation for Mathematics Students at WCU

Almost all students who graduate from NC Public School System should have taken MATH I, II, and III in high school. In a few cases, students are permitted to take MATH I, II, and another mathematics course. MATH I, II, and III cover the content found in MATH 130 at WCU. Many times, however there is a lag in the number of years that have passed between relevant HS mathematics and students' enrollment in MATH 130 or 146 at WCU. This exacerbates the problem of many students' inability to succeed in MATH 130.

In 2016-2017, the Mathematics and Computer Science Department piloted use of ALEKS (Assessment and Learning in Knowledge Spaces) which is an online mathematics learning system that creates individualized remediation programs for each student. It can also place students according to their proficiencies. This software was piloted in all 12 College Algebra courses during that academic year. One of their findings was that ALEKS served very well as a placement tool (as measured by DFW rates). Another take-away from the pilot was that ALEKS could serve as an effective remediation tool if students felt incentivized to use it (Kearns, Lail, Lawson, & Wagaman, 2017).

RECOMMENDATIONS

After consideration of relevant literature, data, trends, interviews, and professional organization recommendations, the Task Force presents the following three recommendations.

Recommendation 1: Create a new STEM mathematics track to Calculus I by eliminating College Algebra and modifying MATH 146 to a two-course Precalculus sequence with significant algebra support. Students in majors that do not require a course like Precalculus to obtain a mastery of functions and algebraic structures should be strongly encouraged to take MATH 101, MATH 170, or MATH 221 instead.

Recommendation Details

The following sequence recommendation is as follows:

Precalculus I (4 credit hours): Functions with a focus on Chapters 1-6, 11 of the current MATH 146 text and a just-in-time College Algebra review. The current textbook already offers just-in-time algebra review modules for each section which can be incorporated more predominantly in this course.

Precalculus II (4 credit hours): Functions with a focus on Chapters 7-10 of the current MATH 146 text and just-in-time College Algebra review. Again, the current textbook offers just-in-time algebra review modules for each section which can be incorporated more predominantly in this course. This course could have additional topics such as Chapter 12: Vectors, Chapter 13: Sequences and Series, Chapter 14: Parametric Equations and Conic Sections or other topics for preparation for Calculus I as identified by the Department.

Suggested Path to Implementation

- ☐ Implementation will require having conversations with all impacted departments prior to proposing catalog changes. Major programs that list Math 130 as a possible requirement, require MATH 146 only, and require MATH 146 and/or other mathematics courses, will need to be approached about how this structure fits with the needs of their students. This should be done as soon as possible. In our Task Force's preliminary conversations with other departments, it appears that Precalculus II would cover the right topics for majors like construction management and natural resources management, but we need to see if the new structure affects them. It is also not clear that Math 130 is currently the right fit for nursing, but we need to have further discussions with them about it. As it stands, nursing majors going on to graduate school are encouraged to take Math 170.

- ☐ Course numbers may have to be modified. Placement thresholds can be designated as current MATH 146 placement would hold for Precalculus II.

- ☐ Other departments who currently have a requirement of MATH 146 in their programs would be advised to update that requirement to whatever course number Precalculus II becomes (knowing that Precalculus I may be a prerequisite based on placement in the same way that MATH 130 is now). Updating MATH 146 to a new number would not require programs to change their credit hour analysis since Precalculus II would be the same credit hours as the existing MATH 146.

- ☐ The Mathematics Curriculum Committee, Gateway Director, and Course Coordinators will need to address sequencing and restructuring of modules in the textbook(s). This includes determining exact content for Precalculus I and II. It also should include considering student learning outcomes to better serve the variety of majors in the class including additional focus on modeling, applications, and data where applicable.

Problems This Recommendation Addresses

- ☐ *P3: Lack of alignment with NC Community College System mathematics track* – This would allow for our Precalculus I and Precalculus II courses to transfer directly with MATH 171(4 credit hours) and MATH 172 (four credit hours) in the NC Community College System. The content would be nearly identical as well especially if we adopted some of the additional topics in Precalculus II.
- ☐ *P5: Duplication of content in College Algebra and Precalculus* – This recommendation would eliminate College Algebra and move the developmental algebra topics to appropriate just-in-time discussions in Precalculus I and II.
- ☐ *P6: Use of College Algebra as a terminal Liberal Studies course when other courses are better-suited to serve this purpose* – Since College Algebra would be eliminated, it would no longer serve as a LS course. Any STEM student taking Precalculus I, II, or Calculus I could use that course to fulfill their LS requirement.

Future Considerations and Challenges

- ☐ Providing adequate training for advisors and other departments about changes to curriculum can be lengthy and require significant communication.
- ☐ Working with other departments, programs, and advisors to guide their students to take the most appropriate mathematics courses to meet their requirements can be challenging. Identifying courses that best fit the needs of all students and provide entry points for them will require more conversations with major programs about their needs.

Recommendation 2: Add just-in-time-remediation in the form of required corequisite lab for students in Precalculus I and II. Corequisite labs should be student-centered environments where students work collaboratively on well-defined tasks and receive immediate feedback on their work.

Recommendation Details

- ☐ Precalculus I and II would both consist of three hours of regular lecture hours and 1 hour of corequisite lab.
- ☐ The structure of corequisites' size, length, and frequency would be: One hour per week face-to-face as well as additional computer-based weekly modules done as homework for a full semester class; it

would be mandatory for all students. The corequisite course should be capped at 20 students from the same course and led by a full-time instructor and a trained student assistant. Therefore, each section of the course is broken into two corequisite sections. The corequisite instructor(s) would meet weekly with course instructors.

- ☐ The registrar would attach the corequisite to the course so that when a student registers for a Precalculus (3 credit) section, they are prompted to enroll in the one-hour corequisite (1 credit). Note that makes Precalculus I and Precalculus II both 4 credit hour courses.
- ☐ This would be launched using the model where all faculty members assigned to teach a Precalculus I and/or Precalculus II lecture section(s) meet with the corequisite instructor(s) each week. The primary purpose of these relatively brief one-on-one meetings is for the faculty member to identify for the corequisite instructor the specific algebraic "problem areas" that students would likely encounter in the lectures during the week. This would help insure that students receive targeted "just- in-time" remediation needed for understanding.
- ☐ During the 1st and 6th weeks of class (after 5-week grades are posted), time could be spent on how to study for an exam and take notes, as well as other successful student practices. It is recommended that the student assistant lead some of the discussions on learning strategies so that students will be hearing from a peer. It is also recommended that attendance in the corequisite courses be required and each week's session include some sort of graded assignment. These weekly assignments will further reinforce the specific math concepts taught in both the main course and in the corequisite course. Weekly assignments from the corequisite course are not intended to replace homework from the main course, but rather they are designed to supplement and reinforce the homework assigned by the course instructor by completing remediation content. Both the student's attendance and weekly corequisite graded assignments should be linked to the course grade to motivate each student to achieve his or her very best. The online portion of the corequisite class provides students with additional feedback and is a means for us to assess their progress. Weekly assignments could be accomplished with an online tool like ALEKS if it were affordable and customizable to fit a just-in-time model for remediation.

Suggested Path to Implementation

- ☐ The Department would need to hire or identify full time instructors to teach the corequisite courses. Involving other department's instructors and graduate students might be a way to gain a larger pool of corequisite instructors.
- ☐ Similarly, the Department would identify students who are qualified to be assistants during class in the corequisite course.

- ☐ The Department will need to discuss a timeline for implementation based on resources needed to ensure a smooth transition and identify human and material resources needed.
- ☐ The Department would need to investigate the affordability of using ALEKS or some other software to supplement the lab instruction.

Problems This Recommendation Addresses

- ☐ *P1: Variance in preparedness for college-level mathematics* – Just-in-time remediation in the form of corequisites offers students with variance in algebraic preparation an option to enter Precalculus I or II with support for algebra remediation. It will also strengthen algebraic competencies of stronger students.
- ☐ *P2: No formal mathematics remediation options for underprepared students* – Corequisites offer more personalized formal remediation for students who are not prepared to enter Precalculus without support.
- ☐ *P4: Increasing number of underprepared STEM majors in need of a Precalculus and Calculus* - Although our department cannot control the mathematical readiness of students entering WCU, the corequisite structure could provide students opportunities to enroll in higher mathematics like Precalculus sooner while providing remediation to all underprepared students.

Future Considerations and Challenges

- ☐ Many universities already engaged in corequisite models indicate that scheduling can be difficult for the corequisite sections. In addition, STEM labs with conflicting times must be considered.
- ☐ Recruiting qualified instructors for corequisite labs might prove challenging. We recommend that a full-time faculty member be hired primarily to run corequisite sections. Faculty members and graduate students from other disciplines might be considered as leaders of corequisite courses too.
- ☐ Students in corequisite labs could be further subdivided weekly into small groups to provide more detailed and specific remediation for specific topics based on students' individual abilities.

Recommendation 3: Provide funding to recruit, train, and develop a deeper tutor pool for the Math Tutoring Center (MTC) in addition to tutors who are working with the corequisite courses.

Suggested Path to Implementation

- ☐ The MTC would need to employ tutors to offer peer-help and peer-delivered study skills workshops that support corequisite lab content.
- ☐ The MTC and Department would align tutor training to serve the corequisite model. Student assistants could be trained for the corequisite classes along with training sessions for student tutors.

Problems This Recommendation Addresses

- ☐ This recommendation doesn't speak directly to the problems P1-P6 in the charge. It is the result of a problem that we identified in our research with Kennesaw State University and Delaware Valley University's adoption of a corequisite structure. KSU lost staffing of their mathematics tutoring center because those students were recruited to lead SI sessions. To avoid this potential problem, it is recommended that an additional pool of tutors be recruited and trained to support instructor(s) teaching the corequisite sections. DVU found that identifying more students than they needed to support their SI program allowed for less scheduling conflicts. A deep pool of trained tutors offers support for the corequisite sections as well as the general tutoring needs of WCU students in other mathematics courses.

Future Considerations and Challenges

- ☐ If a computer-based component (i.e. ALEKS) exists within the corequisite course, there may be an increase in students using the Mathematics Tutoring Center computers or other lab computers.
- ☐ There may be a possible depletion of Mathematics Tutoring Center staff if they are recruited from the tutoring center and used to facilitate corequisites.

Assessing the Goals

Goals G1-G5 of the task force presented at the beginning of this document are restated below as well as links to suggested assessment strategies A1-A8 to capture efficacy and effectiveness of the goals as demonstrated by implementation of the previous three Recommendations in Table 3.

We recommend the following assessment strategies for our goals. Each of the assessments below are meant to be administered to draw comparisons to students prior to implementation of the recommendations versus after implementation. Details would need to be worked out about which assessments would be best to implement and a timeline for assessment would need to be established.

A1: Compare DFW rates before and after implementing the Recommendations

A2: Compare students' GPAs before and after implementing the Recommendations

A3: Compare percentages of students who repeat courses and student demographics before and after implementing the Recommendations

*A4: *Compare efficacy and effectiveness of student learning outcomes before and after implementing the Recommendations*

*A5: *Compare student beliefs, satisfaction, and/or engagement in courses before and after implementing the Recommendations*

*A6: *Compare decision-making process for students when choosing a mathematics course before and after implementing the Recommendations*

A7: Compare graduation percentages and time taken to graduate for STEM mathematics students before and after implementing the Recommendations

A8: Compare the number and quality of MTC mathematics tutor pool before and after implementing the Recommendations

*Data does not currently exist and would need to be gathered prior to implementation of recommendations for pretest

TABLE 3

Goals	Suggested Assessments
G1: Lessen DFW rates in STEM track mathematics courses without compromising necessary content	*A1, A2, A3, A4, A7*

G2: Prepare students more effectively for the mathematical topics currently in Precalculus and Calculus while still making it feasible for students to complete mathematics requirements for STEM majors within 4 years	*A1, A2, A3, A4, A5, A7*
G3: Align more meaningfully with Community College classes to eliminate barriers for transfer students	*A1, A3, A7*
G4: Place STEM students in the most appropriate courses according to their major program needs given their preparedness level	*A1, A3, A5, A6, A7*
G5: Continue to collaborate with the Mathematics Tutoring Center to address the remediation needs of mathematics students	*A8*

FUTURE DIRECTIONS: BEYOND THE CHARGE

The 2020 Vision

The Charles A. Dana Center at The University of Texas at Austin defines a STEM-Prep Mathematics Pathway as "a sequence of courses designed to prepare developmental-level mathematics students interested in STEM (science, technology, engineering, or mathematics careers) to enter – and succeed in – calculus and other technical courses that require strong algebraic skills and a mastery of functions". (Charles A. Dana Center, 2015). They recommend that a two-course sequence of functions, Reasoning with Function I and II, serve as preparation for calculus courses. The DANA Center's conceptualization of Pathways means that students who enter a pathway should do so with the intention to complete it and that a pathway is intentionally designed with certain student learning outcomes that support the needs of majors in that pathway. Many universities' gateway mathematics courses may be designed to serve as prerequisites, but they are often taken as terminal courses. Moreover, traditional courses can lack the cohesiveness vision of a pathway in how best to support the majors enrolled in them and meet their remediation needs for success at higher-level STEM coursework.

Although our task force wasn't charged with creating a Pathway Model for Calculus I, we recognize that a STEM Mathematics Pathway could be a very effective tool for the department. If implemented well, a STEM Pathways Model can address goals of the WCU Strategic Plan: 2020 Vision in addition to Goal 1.5 regarding barriers with NCCCS students (Western Carolina University, 2018a). Pathways including a STEM Math Pathway should be intentionally designed around the needs of the majors of students in the courses. It should include applications and connections to their fields of study and focus on

modeling practices. Courses should be constructed with the input of faculty members in affected disciplines. This process would align well with Goal 1.4 for Academic Excellence: Enhance programs that include cross-curricular, applied, and international/global awareness opportunities for all students. (Western Carolina University, 2018a)

Additionally, according to the Dana Center, one of the primary goals for Math Pathways is to eliminate barriers to access of high-quality mathematical experiences; barriers that they claim disproportionately affect minority students and underrepresented students who are placed in remedial courses at a higher rate and thus are prone to more repetition of these courses (Charles A. Dana Center, 2016). Adopting Math Pathways corequisite model would allow for more leveling of the playing field. This directly addresses Goal: 3.2.1 of the Inclusive Excellence Directive: Ensure that diversity, equity, and inclusion are foundational aspects of educational offerings (Western Carolina University, 2018a).

We suggest that the department consider the following future directions in our efforts towards generating an effective Pathway Model for mathematics.

STEM Math Pathways

- Collaborate with other departments and programs and collect information about their majors' mathematical needs
- Update student learning outcomes in STEM track mathematics courses so they better align with the needs of diverse majors
- Offer STEM track mathematics that engage students in a variety of mathematical practices including modeling, data analysis, and technological software enhancements

Non-STEM Math Pathways

- Consider formal math pathways for undeclared students
- Identify other pathways e.g. Statistics Pathway, Quantitative Reasoning Pathway, Liberal Studies Pathway, Mathematics Education Pathway, etc. and develop/supplement sequencing and coursework for them where needed, including consideration of SI/Corequisites for other pathways
- Collaborate with other departments on the mathematical needs of their students for various majors – design gateway mathematics courses with this in mind
- Update Student Learning Outcomes in other gateway courses so that they better align with the needs of diverse majors

Faculty Engagement and Pedagogy

- Encourage Professional Development opportunities for faculty members to develop materials for teaching courses targeted for certain majors beyond mathematics
- Encourage scholarship of teaching and learning research each faculty member's own classrooms for the purposes of studying student engagement in course work in our new models
- Consider the degree of alignment from instructor to instructor on various pathways courses

Advising, Transfer, and Student Success Services

- Work closely with advising and the Mathematics Tutoring Center with new steps we take
- Collaborate with stakeholders on the campus regarding the restructuring of mathematics courses and seek buy-in from all involved
- Consider additional pathway models that provide alignment for transfer students coming from regional community colleges, UNC institutions, and beyond

Data

- Collect and analyze data on the efficacy of new pathway implemented recommendations
- Continue to study data already available around promising practices for pathways

Placement

- Devise or revise placement thresholds for courses that are restructured for various pathways
- Develop a policy that requires or strongly suggests that students take mathematics courses as soon as they enter the university while providing just-in-time remediation where needed

Finally, although the recommendations in this report addressed some of the problems and limitations of the current STEM mathematics track at WCU, they are designed to be only a first pass at creating an effective Math Pathways program at WCU. In February of 2019 the UNC Math Pathways Task Force will release its findings and recommendations for Math Pathways for the UNC system campuses. This document will extend well beyond the STEM Pathways. While we believe that our task force's recommendations are complementary to the UNC task force's upcoming recommendations, there is much work yet to be done. During our time together as a task force, we shared various ideas about directions that were beyond the scope of the STEM Math Pathways or just weren't feasible to attempt soon. We hope that the department will continue to invest its attention and resources in this initiative.

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APPENDICES

APPENDIX A

University	*Courses Leading Up to Calculus*	*Placement / Notes*
Kennesaw State University	i. College Algebra (3) and ii. Trigonometry (3) or iii. Precalculus (3) iv. Calculus (4)	i. and ii. 2.8 HS GPA, ACT 23, SAT 570, or placement test via ALEKS iii. 3.0 HS GPA, ACT 25, or placement via ALEKS
Murry State University	i. remedial course (NC) ii. College Algebra (4+1coreq) iii. Precalculus (5) iv. Calculus (5)	ii. ACT 21 for 4 credit hour class, and ACT 19 and 20 for 5 credit hour corequisite course iii. ACT 23 iv. ACT 26
Radford University	i College Algebra (3) ii. Precalculus (3) III. Calculus (3)	ii. B- or better in HS Algebra II iii. C or better in Precalculus, or 550 SAT/23 ACT, or placement exam passing score
Salisbury University	i. College Algebra (3) ii. Precalculus (3) iii. Calculus (4)	i. HS Algebra I and II ii. HS Algebra II and Plane Geometry iii. Precalculus course or equivalent
Sam Houston State University	i. Precalculus, Algebra (3) ii. Plane Trigonometry (3) iii. Elementary Functions (4) iv. Calculus (4)	i – iii. Placement test iv. Grade of C or better in Elementary Functions
SE Missouri	i. Precalculus Algebra (3) ii. Precalculus Algebra with integrated review (5)	i. ACT 22 ii. ACT 15-21 iii. Grade of C or better in Precalculus A

	iii. Precalculus (geometry/trig) (3) iv. Calculus (5)	iv. ACT 26, or Precalculus B grade of C or better
SUNY Oswego	i. College Algebra (3) ii. Precalculus (3) iii. Calculus (4)	Placement test via ALEKS for all… i. High school Math 3 ii. College Algebra or placement iii. Precalculus (either from here or from high school) or placement
University of Central Missouri	i. Intro Algebra (NC) ii. Intermediate Algebra (NC) iii. Precalculus Algebra (3) iv. Precalculus Trig (2) or v. Precalculus (5) vi. Calculus (5)	i. ACT < 17 ii. ACT 17 – 21 Note that Precalculus is the combination of Precalculus Algebra and Precalculus Trigonometry

Note. All information in this table was obtained through personal communications during interviews with representatives from the universities.

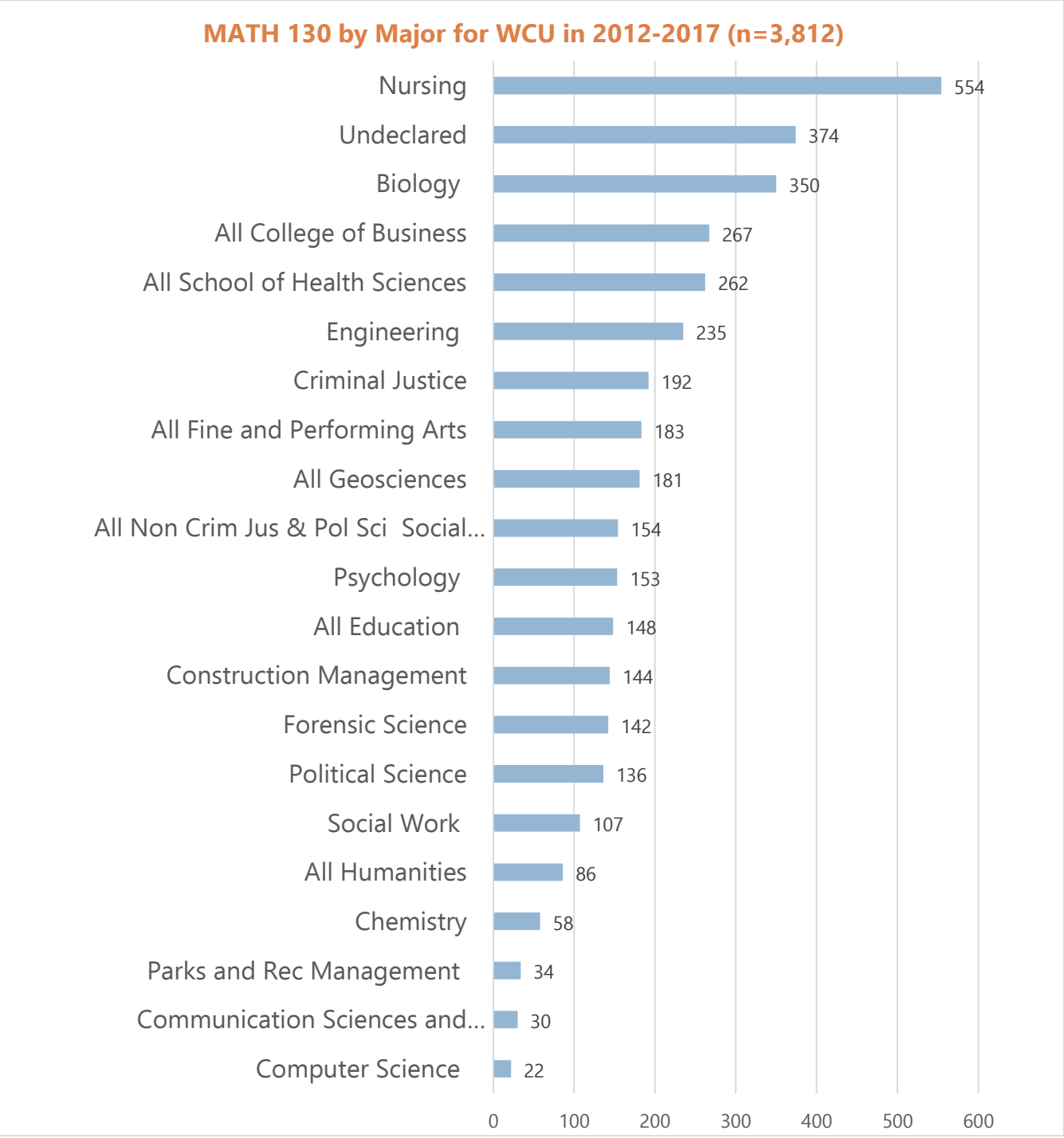
APPENDIX B

University	Corequisite and/or Supplemental Instruction in Calculus Prerequisites
Kennesaw State University	They use certified SI instructors (using the formal definition described earlier in this document) for sections of courses with low pass rates. SI leaders are students who attend half of the classes and go through 4 hours of training. Students are not allowed to be required to attend SI and recording attendance at SI meetings is not allowed. Note that because their best students are SI leaders, there are not enough good students to run a general tutoring center, so they don't have one. In both Precalculus and Calculus, they have Learning Assistants (LA) who are students who go through one hour of training and help during class.
Murry State University	They use a corequisite model in College Algebra for students with lower SATs. It is mandatory, but not for credit.
Radford University	No corequisite or supplemental instruction model offered now
Salisbury University	They have a mandatory 1-hour, non-credit bearing corequisite which is included in their calculus grade. They mentioned that scheduling can get tricky for corequisite sections.
Sam Houston State University	The state pushed them into a corequisite model for Precalculus algebra. They have been using this model for one year and it looks good so far. Currently 50% of students are in it, and they are moving to having 75% of the students in it. Students are allowed test out. Graduate students teach the corequisite courses. Students in the corequisite classes are now passing at a higher rate than those in non-corequisite courses.
SE Missouri	They have a Precalculus A Class with integrated review. According to the interview, this combines A and B. Typically their Precalculus A class has 60 students and is taught in a computer room with an instructor or professor plus a graduate student. It is a 3-credit hour course. Precalculus A with integrated review is in a more traditional setting, is 5 credit hours, and is capped at 30 students. The framework of the course covers topics as a story of functions.
SUNY Oswego	They tried to radically redesign their College Algebra class. They had a traditional class that met one day per week and labs with student assistants the other two

	days. Students complained about it, so they have reverted to a traditional College Algebra class. They have also tried running two-hour Calculus review classes in the evening, but students found it difficult to come. In addition, they have considered dividing College Algebra into modules because the university is pressuring them to get students into Calculus sooner, but it was a scheduling problem, and they have not done it.
University of Central Missouri	For College Algebra, half of the students are required to take the corequisite class. Each corequisite course is linked to two sections of the main course and is taught by adjuncts. Roughly half of one College Algebra class and half of another College Algebra class come together to make a single corequisite class. The original classes have around 35 students each. The corequisite classes has around 20 students. They are considering just offering a 5-credit hour College Algebra with Review course.

Note. All information in this table was obtained through personal communications during interviews with representatives from the universities.

APPENDIX C



Note. Western Carolina University(2018b)