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# Chapter 3

## CAREER-RELEVANT MATHEMATICS PATHWAYS: ON THE ROAD TO STUDENT SUCCESS

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### Abstract

UMBC, a diverse public research university, has a reputation for producing highly capable undergraduate scholars. Unfortunately, many students place into mathematics courses at a lower level than those that offer degree credit or an “M” designation, which is a requirement of the General Education Program (GEP). This chapter provides an in-depth description of the institutional transformation process from a singular mathematics course pathway designed for science, technology, engineering, and mathematics (STEM) majors to one that includes an alternate pathway based on career-relevant mathematical skills for non-STEM majors. This new pathway development involved the creation of a course entitled Quantitative Literacy, which is intended for students who place into a developmental math course (based on the university math placement test) and are pursuing a major that does not require calculus or an algebra-intensive course. Quantitative Literacy focuses on algebraic and numeric skills in the context of applications and problem-solving to prepare students for either Introduction to Statistics for the Social Sciences or Contemporary Mathematics, both of which carry GEP credit and an “M” designation. Data analytics are used to explore the impact of the new Quantitative Literacy course on the progression of non-STEM majors. Challenges and opportunities will be addressed as career-relevant pathways proceed to full institutionalization.

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In 2015 the Organization for Economic Cooperation and Development (OECD) ranked their 35 member countries in terms of college attainment, and the U.S. was placed tenth<sup>6</sup> (Fry, 2017). As of 2017, 47.76% of Americans age 25-46 had completed a tertiary level of education<sup>7</sup> (OECD, 2019), and, according to the U.S. Census Bureau (2017), 39% of Marylanders aged 25 and older held a college degree (for the period 2013-2017). In 2009, then-governor Martin O'Malley established the goal that by 2025, 55% of Maryland residents ages 25 to 64 would have a college degree. In order to reach the goal of 55% by 2025, the Maryland Higher Education Commission (MHEC) issued the Maryland State Plan for Postsecondary Education, which noted several areas of educational reform that need to be addressed, including the significant issue of "College and Career Readiness" (MHEC, 2013, pp. 9-10).

MHEC estimates that nearly 60% of recent high school graduates enrolling in Maryland public colleges and universities need some level of developmental instruction, which is intended to provide basic instruction in mathematics, English, or reading to students who are not prepared for college-level curriculum at the time of enrollment (MHEC, 2013, p. 9). Longitudinally, placing students into developmental math courses has resulted in an alarming situation, with only 27% of students enrolled in developmental math courses going on to

complete their degrees (Center for Community College Student Engagement, 2016; Snyder, de Brey, & Dillow, 2016). Prior studies have shown that students' performance in mathematics is not necessarily due to a lack of mathematical ability, but rather not being able to apply their mathematical abilities in a real-life context (National Center for Education Statistics, 1997; Steen, 2001). One reform initiative addressing the problem of developmental math courses serving as a barrier to degree completion is the Maryland Mathematics Reform Initiative-First in the World project (MMRI-FITW). The MMRI-FITW is a collaborative effort among select University System of Maryland public four-year institutions and two-year community colleges in Maryland. The objective of MMRI-FITW is to develop, implement, and evaluate a statistics pathway intended to aid students in developmental courses in reaching degree completion efficiently by accelerating their progress into credit-bearing mathematics courses at the postsecondary level.

### **Institutional Context**

The University of Maryland, Baltimore County (UMBC) is one of 12 institutions in the University System of Maryland, and one of five four-year institutions participating in the MMRI-FITW. Founded in 1966, UMBC originally focused on preparing students for professional schools in downtown

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<sup>6</sup> The OECD definition of college attainment is the percentage of 25- to 34-year-olds completing at least an associate degree.

<sup>7</sup> "Population with tertiary education is defined as those having completed the highest level of education, by age group. This includes both theoretical programmes leading to advanced research or high skill professions such as medicine and more vocational programmes leading to the labour market" (OECD, 2019).

Baltimore. However, UMBC has rapidly transformed into a public research university, and is now classified by the Carnegie Foundation for the Advancement of Teaching as a Research University with High Research Activity (“UMBC Research Fast Facts,” n.d.). UMBC prides itself on offering a distinctive undergraduate education characterized by a strong liberal arts and science foundation, and an array of graduate programs emphasizing selected areas of science, engineering, information technology, public policy, and human services. Students come from across the country and more than 100 nations, giving UMBC a highly diverse student body and an inclusive environment for teaching and learning. Enrollment in Fall 2017 was 13,662, which was composed of 11,234 undergraduate and 2,428 graduate students. A substantial number of UMBC’s undergraduate population consists of transfer students from other institutions, with about half of each year’s new undergraduate students coming from community colleges.

### **Math Placement at UMBC**

Each student entering UMBC as a direct-entry freshman is required to take a math placement exam in order to enroll in their first semester of classes. The goal of the math placement exam is to ensure that students are placed in the correct level of math according to their mathematical abilities and completion of previous foundational math courses. Prior to 2016, UMBC utilized a placement exam which was created by UMBC’s Department of Mathematics and Statistics. All incoming students took a “base” version of the placement exam that covered topics to determine “algebra

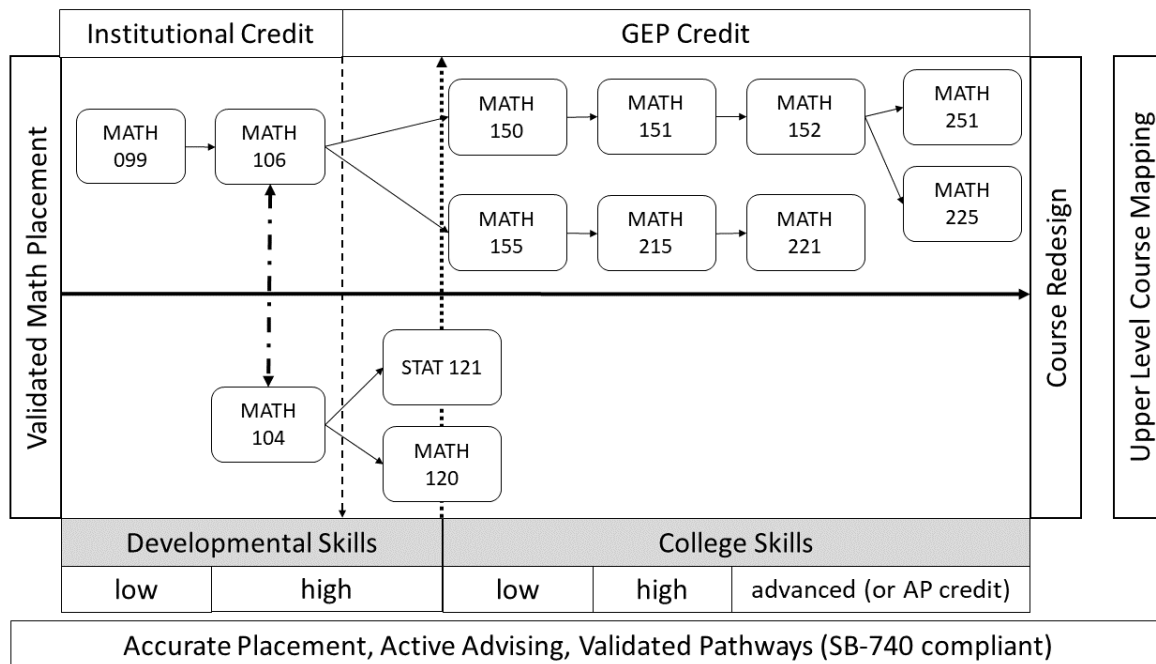
readiness.” Students who intended to major in a discipline that required completion of calculus had to take an additional section of the placement exam that determined “calculus readiness.” The placement exams were administered to students in an online format, allowing the students to take them from home prior to attending orientation. However, because this placement exam was created at UMBC, it was never validated as an accurate method to place students in the proper math courses. Difficulties also arose trying to compare placement guidelines between institutions that used a validated math placement test, such as ACCUPLACER®.

In the Fall 2016 semester, UMBC began utilizing ALEKS® Placement, Preparation and Learning (PPL) for math placement purposes. ALEKS® PPL offers several advantages over the UMBC-created placements test. ALEKS® PPL uses a single assessment of 30 questions or fewer to place students from basic math up through Calculus I, eliminating the need for two versions of the placement exam. The ALEKS® PPL software is also a validated testing method that uses artificial intelligence to “efficiently assess course readiness” and accurately place students into the correct math course (“What is ALEKS® PPL?”, n.d.). ALEKS® PPL can be administered fully online, and students can repeat the placement exam one time to improve their placement score. An additional critical component of ALEKS® PPL is access to “Prep and Learning Modules” as a means for students to review content and concepts that they score poorly on in the placement exam (“What is ALEKS® PPL?”, n.d.).

## Math Pathways at UMBC

The implementation of a validated math placement exam (ALEKS® PPL) was the underpinning of math pathway reform at UMBC. The top half (above the thick, solid horizontal line) of *Figure 3-1* shows the algebra-based math pathway that students pursuing majors that require a calculus-based course will follow, including the possible courses these students can take to fulfill their General Education Program (GEP) math requirement. The bottom half (below the solid horizontal line) of *Figure 3-1* shows the new statistics-based pathway for students pursuing majors that do not require a calculus-based course, including the possible courses that these students can take to fulfill their GEP math requirement. The gray boxes at the very bottom of *Figure 3-1* correspond to the mathematical skill levels required to place into the corresponding mathematics

courses in the pathways depicted above. The implementation of a new statistics-based pathway at UMBC led to course redesign and creation of the MATH 104 course, Quantitative Literacy. (For a “key” to the figure, listing course titles for associated course numbers, see Table A-1 in Appendix A). Interconversion between the statistics-based pathway and algebra-based pathway is possible in that students have the ability to transfer between the developmental courses, Quantitative Literacy (MATH-104) and Algebra and Elementary Functions (MATH-106), depending on which pathway best fits their major (indicated by the dot-dashed arrow between the two courses in *Figure 3-1*). However, transferring pathways requires individual advising of students and the expectation that the student will likely need to complete additional coursework to complete the math pathway.



*Figure 3-1. Mapping of math pathways and placement at UMBC*

The use of the ALEKS® PPL also allowed for the adjustment of cutoff scores for placement into GEP-credit-level math (indicated by the vertical dotted arrow). Math pathway reform at UMBC has led to the course redesign and the continuous process of improving student learning outcomes for all mathematics courses. Upper-level course mapping has also been used to target and eliminate bottlenecks in the mathematics pathways that impede graduation, as well as in the development of course plans for math pathway completion.

### ***Algebra Pathway***

UMBC requires students to complete one mathematics course at the “college skills” level to earn GEP credit towards their degree (see *Figure 3-1*). Prior to the implementation of the MMRI-FITW project in Fall 2015, UMBC had a single algebra-based mathematics pathway that students could pursue to fulfill their math general education program requirements. Courses that fulfilled the GEP requirement at the “college skills” level included Introduction to Contemporary Mathematics (MATH 120), and Introduction to Statistics for the Social Sciences (STAT 121), as well as courses that focused on precalculus and increasingly advanced content (for a list of courses, see Table A-1 in Appendix A).

Students who scored two levels below GEP-credit math in the “low” developmental skills range on the UMBC-developed placement exam were placed into Introductory Algebra (MATH-099). Introductory Algebra was designed for students new to algebra content, and covered topics such as properties of integers and real numbers, linear equations and inequalities, and operations on

monomials and simple polynomials. Students who scored one level below GEP-credit math or in the “high” developmental skills range on the UMBC-developed placement exam were placed into Algebra and Elementary Functions (MATH 106). Algebra and Elementary Functions serves as an introduction to the basic techniques and functions of mathematics with topics including linear equations and inequalities, quadratic equations, polynomials, and rational functions and their inverses. Completion of both algebra-focused developmental courses earns students institutional level credit but does not fulfill the UMBC GEP requirements for graduation. Algebra and Elementary Functions was designed for students pursuing majors that require the completion of at least one calculus-based course (mainly STEM disciplines); however, 56% of the majors offered at UMBC do not require the completion of a calculus-based course.

Prior to the mathematics pathway reform that was implemented with the MMRI-FITW project, all incoming UMBC students who scored at the “developmental skills” level on the UMBC-developed placement exam only had the option to enroll in Introductory Algebra (MATH-099) or Algebra and Elementary Functions (MATH-106), regardless of their intended major. For students in disciplines that did not require the completion of a calculus-based course, Algebra and Elementary Functions was a challenging course that served as a barrier to math GEP completion, and the course content was less relevant to their intended career path. Regardless of student performance, the original pathway was improperly structured for students in a major

not requiring calculus and more appropriate course content was implemented with the new statistics pathway.

### ***Statistics Pathway***

In Fall 2015 UMBC developed a new statistics-based pathway as part of the MMRI-FITW (see bottom half of *Figure 3-1*). Although this new pathway at UMBC is in fact a combination of statistics and quantitative reasoning-based approaches, it will hereafter be referred to as the “statistics-based” pathway to be consistent with MMRI-FITW. Development of a statistics-based pathway involved creating a new developmental-level statistics course called Quantitative Literacy (MATH 104). Quantitative Literacy focuses on algebraic and numeric skills in a context of applications and problem-solving to prepare students for Introduction to Statistics for the Social Sciences (STAT 121) or Contemporary Mathematics (MATH 120). Topics include quantitative relationships, algebraic reasoning, functional reasoning, and probabilistic and statistical reasoning with the incorporation of quantitative communication skills. Quantitative Literacy was designed for students who score in the “high” developmental range on the ALEKS® PPL placement exam and are not intending to major in a discipline that requires completion of a calculus-based course.

The curriculum for Quantitative Literacy was designed by the Department of Mathematics and Statistics at UMBC under the guidance of the MMRI-FITW faculty liaison, Dr. Elizabeth Stanwyck. However, core course topics were established by the University System of Maryland through workshops with faculty across multiple institutions involved

in the MMRI-FITW project. Adjusting the level of difficulty of the Quantitative Literacy course has been an evolving process since its implementation. Math faculty members at UMBC have been evaluating student success in the next course (generally Introduction to Statistics for the Social Sciences) and adjusting the difficulty level of the course topics. The overall goal is to find a balance in the material where students feel confident in the topics, but the course content is still advanced enough that students master the skills required to succeed in their subsequent required GEP math course.

During the process of curriculum development, the department was careful to ensure content alignment between Quantitative Literacy and the subsequent GEP courses, Contemporary Mathematics and Introduction to Statistics for the Social Sciences. Introduction to Statistics for the Social Sciences is the GEP course that the majority of the students enroll in after completion of Quantitative Literacy. The curriculum for Introduction to Statistics for the Social Sciences was aligned across all University System of Maryland Institutions. Faculty from the University System of Maryland Institutions met and discussed the skills required to succeed in Introduction to Statistics for the Social Sciences, and through a series of meetings determined a common set of skills required for the GEP math course. Math faculty who teach Introduction to Statistics for the Social Sciences and Contemporary Mathematics were also consulted during the curriculum development of Quantitative Literacy to further ensure content alignment between Quantitative Literacy and the subsequent GEP math courses.

In a separate but related initiative, the statistics pathway at UMBC is also being further evaluated by the Aligned Learning in Statistics (ALiS) project. ALiS is a collaborative initiative among ITHAKA, the Urban Institute, Acrobatiq (by VitalSource), and select institutions in the University System of Maryland, to explore the effectiveness of a new adaptive learning platform for student success in STAT 121.

In addition to the development of Quantitative Literacy, the implementation of the validated ALEKS<sup>®</sup> PPL placement test led to the adjustment of the math placement cutoff scores in the statistics-based pathway (lowered from the position of the vertical dotted arrow to that of the thin, dashed vertical arrow in *Figure 3-1*). The adjusted math placement cutoff scores were initially based on recommendations made by representatives from ALEKS<sup>®</sup> PPL. Students pursuing the statistics-based pathway could achieve a placement score at the higher end of the “high developmental skills” range to the lower end of the “basic college skills” range and still enroll in either Contemporary Mathematics or Introduction to Statistics for the Social Sciences, both of which are GEP-credit-level math courses. In contrast, students pursuing the algebra-based pathway must score at least in the “basic college skills” range on the placement exam to directly enroll in a GEP-credit-level math course, such as Precalculus (MATH 150) or Applied Calculus (MATH 155). This allows

for more students to directly place into GEP-credit-level math and complete their math graduation requirements sooner. The placement cutoff scores are currently being further calibrated for students at UMBC.

### **Lessons Learned and Conclusion**

The creation of Quantitative Literacy and a statistics-based pathway has revolutionized the track to math GEP completion at UMBC for students who do not require calculus-based coursework for their major. The average drop/fail/withdraw (DFW) rate for Algebra and Elementary Functions from Fall 2013 to Spring 2016 (prior to the development of Quantitative Literacy and implementation of the statistics-based pathway) was 33%. In contrast, the average DFW rate for Quantitative Literacy from Fall 2016 to Spring 2018 was 14%, demonstrating that Quantitative Literacy, geared toward the statistics pathway, has been initially more successful than Algebra and Elementary Functions. We have also learned that finding a validated placement testing method that will accurately place students into the correct math course is critical to student success and on-time completion of math GEP requirements for graduation. As Quantitative Literacy and the new statistics pathway continue to be evaluated, we hope to find that this course redesign will help to increase student retention and graduation rates by lowering the barrier to math GEP completion.



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