Reforming Mathematics in Maryland

Stories from the Journey

Dewayne Morgan, Karen Feagin, and Nancy S. Shapiro (editors)

University System of Maryland

Copyright and Acknowledgments

This publication was made possible by a grant from the U.S. Department of Education, through the Fund for the Improvement of Post-Secondary Education (FIPSE), First in the World (FITW) grant program, award P116F150201. The content of the publication does not necessarily reflect the views or policies of the U.S. Department of Education nor does mention of trade names, commercial products, or organizations imply endorsement by the U.S. Government.

Special Thanks

Creating *Reforming Mathematics in Maryland: Stories from the Journey* was a journey itself, and we would like to thank all the organizations and individuals who contributed their time and expertise, in particular Sarah Beaton, Stephanie Hall, Annika Many, Jill Feldman, and Jennifer Flynn. Thank you all for helping make this publication possible.

About the University System of Maryland

The University System of Maryland (USM) is the state's public higher education system. USM's 12 institutions, 3 regional higher education centers, and system office work together to leverage their collective expertise and resources, share best practices, increase the system's effectiveness and efficiency, and advance USM's mission to improve the quality of life in Maryland.

The mission of the University System of Maryland is to improve the quality of life for the people of Maryland by providing a comprehensive range of high quality, accessible, and affordable educational opportunities; engaging in research and scholarship that expand the boundaries of current knowledge; and providing knowledge-based programs and services that are responsive to the needs of the citizens of the state and the nation.

USM fulfills its mission through the effective and efficient management of its resources and the focused missions and activities of each of its component institutions.

USM P-20

The USM P-20 office is housed in the office of Academic Affairs and has both an internal and an external focus. The USM P-20 office works directly with the Departments of Education in the USM institutions and in partnerships with the local school systems to strengthen educational achievement from elementary school through college and beyond and to create programs that encourage students to consider and prepare for college. These partnerships also work at the Pre-K-12 and college levels to improve teacher quality.

About the Editors

Dewayne Morgan is the University System of Maryland's Director of P-20 Partnerships where his primary responsibilities are to develop and monitor policies, practices, and initiatives related to the University System of Maryland's (USM) extensive school-university-business partnership agenda. His major areas of focus include recruitment into STEM degrees and careers, educator preparation and professional development, and college student retention and progression to graduation. Most recently, he has led the creation of the state's new Maryland Center for Computing Education (MCCE) at USM which is designed to expand access to high-quality Pre-Kindergarten-12 computing education by strengthening educator skills and increasing the number of computer science teachers in elementary and secondary education. MCCE has secured $7,000,000 in state support to create the infrastructure for the Center and begin offering services to Maryland teachers and schools. Prior to being named P-20 Director, Dewayne served as the evaluator for multiple multi-million-dollar NSF-funded partnerships that were all designed to increase the number of females and underrepresented minorities in STEM fields. Some of his recent mathematics pathways presentations and research include, "Finding a Balance: Purposeful Math Pathways," presented at the AACU Annual Conference in San Francisco and "First in the World Maryland Mathematics Reform Initiative" in the University of Texas Dana Center's monograph, Emerging Issues in Mathematics Pathways. Before coming to the University System of Maryland Office, Dewayne served as a teacher in Florida public schools and later worked as a family law attorney for children in foster care. Mr. Morgan received education, music, and law degrees from the University of Florida.

Karen Feagin is currently a Ph.D. student at the University of Maryland, in the Applied Linguistics and Language Education program in the College of Education. Her research interests include fair assessment of language learners, language policy in both macro- and micro-contexts, and the relationship between language policy and assessment in K-12 U.S. classrooms. She holds an M.S. in Applied Linguistics from Georgetown University and B.A. in Linguistics from the University of North Carolina, Chapel Hill. Before beginning her doctoral studies, she worked as a language assessment specialist.

Nancy S. Shapiro is Associate Vice Chancellor for Education and Outreach and Special Assistant to the Chancellor for P-20 Education at the University System of Maryland. As the principal investigator on major federal grants totaling over $30 million dollars from and the National Science Foundation (MSP) and the U.S. Department of Education (TQE), she has worked to build sustainable partnerships between colleges, universities and public schools which support high quality professional development in Science, Technology, Engineering and Mathematics (STEM) content areas and prepare future teachers for urban schools. She led a System-wide initiative on Academic Transformation and Course Redesign, with special emphasis on redesigning undergraduate general education courses. She regularly convenes the education college deans and directors across the state of Maryland as policy advisory group, and in 2014 authored the P-20 Task Force Report on Teacher Preparation for the Maryland General Assembly.

Before coming to the University System Office, Dr. Shapiro served as the Founding Executive Director of the College Park Scholars program, and directed the writing programs at the University of Maryland, College Park. She has authored numerous books and articles on creating and sustaining learning communities and has served as an external evaluator and consultant on projects related to STEM teaching and learning, academic transformation, and College Board Affinity Network investment in college access and success. She holds an appointment as Research Scholar in the College of Education at the University of Maryland in the Department of Teaching and Learning, Policy and Leadership.

Dr. Shapiro graduated Phi Beta Kappa from Brandeis University, earned her master's degree at the University of Delaware, and her Ph. D. in Curriculum and Instruction from the University of Maryland.

CONTENTS

Appendices

List of Tables

List of Figures

INTRODUCTION

The story of Maryland's Mathematics Reform Initiative (MMRI) begins with a policy challenge. National studies reveal that over half of community college students are required to take developmental (or remedial) math courses during their time in college (Stigler, Givvin, & Thompson, 2010). Most of these students "do not remediate successfully" (Bahr, 2008, p. 421); when remediation is unsuccessful, a majority of the students do not continue to complete their intended credential. Among community college students more broadly, more than 80% of first-time, full-time students do not complete their degree within three years (Bailey, Jaggars, & Jenkins, 2015, p. 5). In Maryland, almost one-third of all college students transfer between Maryland's two-year and four-year public institutions (Maryland Higher Education Commission, 2019). Developmental mathematics courses were costing the state $7,000 per student at community colleges and $9,000 per student at public universities, and more importantly, dashing students' hopes and dreams. Our policy leaders challenged us: What could we do about that?

In 2014, then-Chancellor William E. ("Brit") Kirwan charged a statewide task force to study the problem and make recommendations aimed at reducing students' time in non-credit mathematics courses and accelerating their progress toward a degree. Thus, the Maryland Mathematics Reform Initiative (MMRI) was born. The resulting project became a collaborative effort between the four-year public University System of Maryland institutions and the two-year community colleges in Maryland in the service of the students and the State. As the work progressed over a five-year time period (2014-2019), we scaled the project to include all two-year and four-year, public and private higher education institutions in Maryland. And our efforts continue.

This project builds on past and current work in Maryland around models of academic course redesign and draws on expertise from the University of Texas Dana Center's New Mathematics Pathways (Dana Center, 2019) to build seamless transfer pathways for students into multiple majors. The MMRI workgroup was charged with making recommendations to improve student success in post-secondary mathematics broadly. Math pathways and co-requisites were two options, and some institutions expressed interest in exploring both options. Ultimately, we decided to partner with the Dana Center to study the effectiveness of the pathways project as part of our U.S. Department of Education FIPSE, First in the World grant.[1] The umbrella policy goals were to modernize current mathematics courses and programs, develop transferable pathways that will lead to greater student retention and academic progress, improve time to degree, and reduce costs to students and to institutions.

We recognized from the outset that the environment for learning and teaching mathematics in higher education has

[1] Award **P116F150201**

undergone and continues to experience significant changes in the areas of

- Student preparedness;
- Student diversity;
- Student career goals and the need for workplace skills (e.g., technology skills, data analysis skills);
- Quantitative skills demanded by more disciplines including, for example, the social sciences; and
- Advances in technology (e.g., software for teaching, learning, and assessment; comprehensive learner records; learner analytics, etc.), among others.

Because of the special role of mathematics in college success and failure, we focused on expanding the first credit-bearing course in a given mathematics sequence, or "gateway math courses" (Bryk & Treisman, 2010), beyond traditional college algebra to include statistics and quantitative literacy, while paying special attention to transfer and transfer pipelines. While this project will likely improve the mathematics pipeline for all students, we expect the biggest beneficiaries to be underserved minority students, who typically come to college with the greatest economic and academic challenges.

Maryland already has a robust transfer policy environment, requiring that any course that fulfills a general education requirement at one public institution in the state must transfer to another public institution as a general education course. The challenge Maryland students faced when we started this work was that the existing mathematics requirement in regulation (Code of Maryland [COMAR]) referred only to an algebra-based calculus pathway, which creates an unnecessary barrier to academic and career-related success for students who are not pursuing STEM majors.

Our first hurdle was to revise and broaden the regulatory language to open the door for new pathways. The process of building consensus around a major policy change to general education was the "secret sauce" that led to the collaborative development of a proposal to the U.S. Department of Education to support the development of new courses and pathways as described in this monograph. If collaboration is the key, appreciation for diversity of institutions, institutional missions, student demographics, and regional distinctiveness is the hallmark of the work. In this collection of essays, eight of our partner institutions and one affiliate institution have stepped forward to describe their work—nine separate lenses focused on "first things first" at each of their institutions. Collectively, they illustrate that common goals, constant communication, collaborative sharing of curricula and professional development, and strong support from leaders create a robust community of practice.

MMRI set out to ensure that all students in Maryland have access to the highest quality, transferable, expanded quantitative reasoning foundational pathways. These reforms have important consequences for students' success, for students' ability to transfer credits between two-year and four-year colleges and universities, and ultimately for more effective and efficient use of Maryland's public resources dedicated to higher education.

Overarching Goals

- MMRI will develop and implement structured pathways in programs of study that are flexible enough to allow for institutional variation but defined in ways that guarantee transfer into multiple majors and programs.
- MMRI will bring mathematics pathways to scale. Many innovations are limited in their relevance and/or fit with institutions of different sizes, missions, or historic contexts. This project is designed to be inclusive of diverse institutions and will draw upon Maryland's long experience in academic transformation to scale *and* sustain these innovations.
- MMRI will draw on internal and external resources and build capacity both within institutions and across Maryland's higher education community. MMRI follows in a successful tradition of prior work in the state with aligned majors' pathways, such as the Associate of Arts of Teaching, the Associate of Science of Engineering, and the two-year to four-year nursing pathway. Each of these degree programs is outcomes-based and guarantees transfer between all two-year and four-year colleges and universities in Maryland.
- MMRI will be phased in over four years to ensure that early adopters can become resources for later adopters and to build capacity so that the project becomes sustainable.

Key Activities

- Establishing state-wide advisory groups for pathways;
- Defining collaboratively agreed-upon outcomes (including engaging social sciences, arts and humanities, and other faculty to ensure quantitative reasoning objectives are aligned with programs of study);
- Developing common curricular materials that can be shared among institutions and be made available online for students at no cost or greatly reduced cost;
- Developing and vetting common advising materials that can be accessed online and/or through institutional resources to ensure students have advising support; and
- Developing and providing modular content support for students in different pathways.

Summary of Content

We started the project with twelve partners: Seven community colleges and five four-year universities[2] and received funding from the U.S. Department of Education's Fund for the Improvement of Post-Secondary Education (FIPSE) First in the World program (P116F150201; 2014-2019). Early on, we expanded our project convenings and

[2] Community colleges: Anne Arundel Community College, Cecil College, Howard Community College, Montgomery College, Harford Community College, College of Southern Maryland, and Garrett College. Four-year universities: Coppin State University; University of Maryland, Baltimore County; Towson University; University of Maryland University College (now University of Maryland Global Campus); and University of Baltimore.

professional development opportunities to include all the public and private two-year and four-year colleges and universities, inviting them to become "affiliate" members, since we were only funded for the first twelve "early adopters." After the first cohort of students had moved through the first set of new courses, we invited our partners to submit essays for a monograph of case studies. This volume represents the stories of those project partners and affiliates who responded to that invitation. Our community college partners included in this publication were Anne Arundel Community College and Montgomery College, writing together; Harford Community College; and Howard Community College. The four-year institutions who provided chapters in this publication include Coppin State University (partner); Morgan State University (affiliate); Towson University (partner); University of Maryland, Baltimore County (partner); and University of Maryland Global Campus[3] (partner).

We have given some thought to how to navigate among the essays. For those looking for a "sister" institution that is demographically similar to your institution, here is a list with snapshot demographics, in the order the chapters may be found in this publication:

Institution Name	Institution Type	Undergraduate Enrollment
Anne Arundel Community College (AACC)	2-year community college	18,734 (credit students) 7,923 (full-time equivalent)
Montgomery College (MC)	2-year community college	22,875 (credit students) 6,864 (FTE)
Towson University	4-year university	19,818
University of Maryland, Baltimore County (UMBC)	4-year university	11,260
University of Maryland University College (UMUC)	4-year university	47,253
Howard Community College	2-year community college	14,444 (credit students)
Harford Community College	2-year community college	8,225 (credit students)
Coppin State University	4-year university	2,362
Morgan State University	4-year university	6,026

[3] At the time of the work completed as part of MMRI-FITW, University of Maryland Global Campus was known as University of Maryland University College (UMUC). Its name change was officially approved in April of 2019; however, hereafter when referring to the institution and its work with MMRI-FITW, we use "UMUC."

For those looking to learn about different types of reforms that were tried, here is a list organized by intervention strategy:

Developing or revising co-requisite supports to support credit-bearing mathematics courses:

- Coppin State University
- MC-AACC
- Morgan State University

Designing and/or revising developmental mathematics courses in the statistics pathway:

- Harford Community College
- Howard Community College
- MC-AACC
- Towson University
- UMBC
- UMUC

Revising the gateway course in the statistics pathway:

- Towson University
- UMUC

Revising or reconsidering the placement process for students into mathematics courses:

- Howard Community College
- Morgan State University
- Towson University

Navigating and negotiating the role of advising in pathway development:

- Howard Community College
- MC-AACC

For those looking to read a research study, investigating the effects of the institution's educational innovation, here is a list of the universities using research-based frameworks in their chapters:

- Coppin State University (quasi-experimental study)
- Morgan State University (pilot study)

I invite you to immerse yourself in these cases studies and vicariously experience this complex, multifaceted experiment. Each team chose their own perspective, and, as the saying goes, "Where you stand depends on where you sit." I have been privileged to sit at many tables during the development and implementation of the Maryland Mathematics Reform Initiative—and I stand with our students and our teachers. I've learned a great deal over the course of this journey and how much is still to be done.

—Nancy S. Shapiro, Associate Vice Chancellor for Education and Outreach, University System of Maryland

References

Bahr, P. R. (2008). Does mathematics remediation work? A comparative analysis of academic attainment among community college students. *Research in Higher Education*, *49*(5), 420-450.

Bailey, T. R., Jaggars, S. S., & Jenkins, D. (2015). *Redesigning America's community colleges*. Harvard University Press.

Bryk, A. S., & Treisman, U. (2010). Make math a gateway, not a gatekeeper. *The Chronicle of Higher Education*. Retrieved from https://www.chronicle.com/article/Make-Math-a-Gateway-Not-a/65056

Charles A. Dana Center at the University of Texas at Austin. (2019) *The case for math pathways*. Retrieved from https://dcmathpathways.org/sites/default/files/resources/2019-03/CaseforMathPathways_20190313.pdf

Maryland Higher Education Commission. (2019). *2019 data book* [Report]. Retrieved from https://mhec.state.md.us/publications/Documents/Research/AnnualPublications/2019DataBook.pdf

Stigler, J. W., Givvin, K. B., & Thompson, B. J. (2010). What community college developmental mathematics students understand about mathematics. *Math AMATYC Educator*, *1*(3), 4-16.

Chapter 1

A TALE OF TWO CO-REQUISITES: INTEGRATING FOUNDATIONAL SKILLS AND STATISTICS

John Hamman
Montgomery College

Milton Nash[1]
Montgomery College

Beth O'Reilly[2]
Anne Arundel Community College

Darren Smith
Montgomery College

Robyn Toman
Anne Arundel Community College

M. Bess Vincent
Montgomery College

Abstract

As many institutions of higher education begin to explore co-requisite structures for mathematics, we describe two open-access institutions' journeys to creating co-requisite courses that complement a pathways model. Both Anne Arundel Community College and Montgomery College have adopted co-requisite models for helping students to reach general education statistics courses. Anne Arundel Community College started a co-requisite structure in 2015-2016 and has adapted the statewide pathways to fit into that model. Montgomery College started their pathway course in 2016-2017 and has since adapted it to a co-requisite model, beginning in fall 2018. In this chapter, each institution will outline their process, their successes, and next steps to refine the curriculum to maximize student success.

---

[1] Corresponding author: 7600 Takoma Ave., Takoma Park, MD 20912, milton.nash@montgomerycollege.edu
[2] Corresponding author: 101 College Parkway, Arnold, MD 21012, boreilly@aacc.edu

Two large community colleges in Maryland, Anne Arundel Community College (AACC) and Montgomery College (MC), worked together through statewide initiatives to develop effective course options for students to succeed in statistics. One option, supported by the Maryland Math Reform Initiative, funded by the First in the World grant program (MMRI-FITW), is a single-semester pathway course that provides a prerequisite developmental foundation of quantitative knowledge designed specifically to support success in statistics. While pathways improve student success by ensuring that prerequisite course content aligns with programs of study (Massachusetts Department of Higher Education, 2018), national discussions on college completion also focus on the benefits of "just in time" support (Complete College America, 2018). Accordingly, AACC and MC offer students a co-requisite option of enrolling in two courses at the same time: college-level Introductory Statistics and a developmental course that supports the higher-level concepts. Although some institutions approach pathways and co-requisite models as an either/or scenario, AACC and MC arrived at the same conclusion—pathways and co-requisite models can not only coexist, but are both vital to improving student outcomes. In this chapter, each institution will highlight its implementation process, the challenges faced, and the benefits of including both a pathways option and a co-requisite course for maximizing student success in Introductory Statistics.

Statewide Context

Maryland has a Statewide Mathematics Group composed of a large network of faculty and administrators from two-year and four-year institutions, the University System of Maryland, and K-12 representatives from the Maryland State Department of Education, along with policy support from the Maryland Higher Education Commission. The Statewide Math Group wields a wide influence on promoting substantial transformation across Maryland's institutions of higher learning. Shared collective expertise is an extremely valuable agent of change, especially as national conversations highlight the need for developmental mathematics reform. As shown in the diagram below, AACC and MC have a common history of responding to national and statewide efforts aimed at improving student outcomes in developmental mathematics. However, the opportunities from MMRI-FITW marked significant curricular shifts that have allowed AACC to transform an existing co-requisite statistics course into a pathways program, while MC was able to expand its existing pathway course into a co-requisite model for Introductory Statistics. (See *Figure 1-1*, next page.)

Common History of Reform Attempts

Approximately ten years ago, both AACC and MC responded to national conversations about remedial mathematics course redesign by adopting an emporium-based modular curriculum (National Center for Academic Transformation, 2005). The goal was to increase student success by providing opportunities to leverage the power of technology to personalize learning experiences and persist to mastery. Despite these changes, the majority of the students were still not completing the traditional developmental algebra sequence and progressing to credit-level mathematics. At the end of two years, AACC discovered that in a cohort of students, only 3.9% of the Pre-Algebra students and 15.5% of the Beginning Algebra students successfully completed a credit-level math course. Montgomery College found that of the 7,663 students who started at the beginning of the developmental sequence, only 11.8% completed a credit-bearing math course within two years. Both MC and AACC found the emporium model to be the most beneficial for the students who could accelerate through the remedial sequence, especially students pursuing STEM related degrees. Ultimately, the emporium model was a hindrance for students who placed into the lowest level developmental courses as the self-paced structure impeded forward progress for some students.

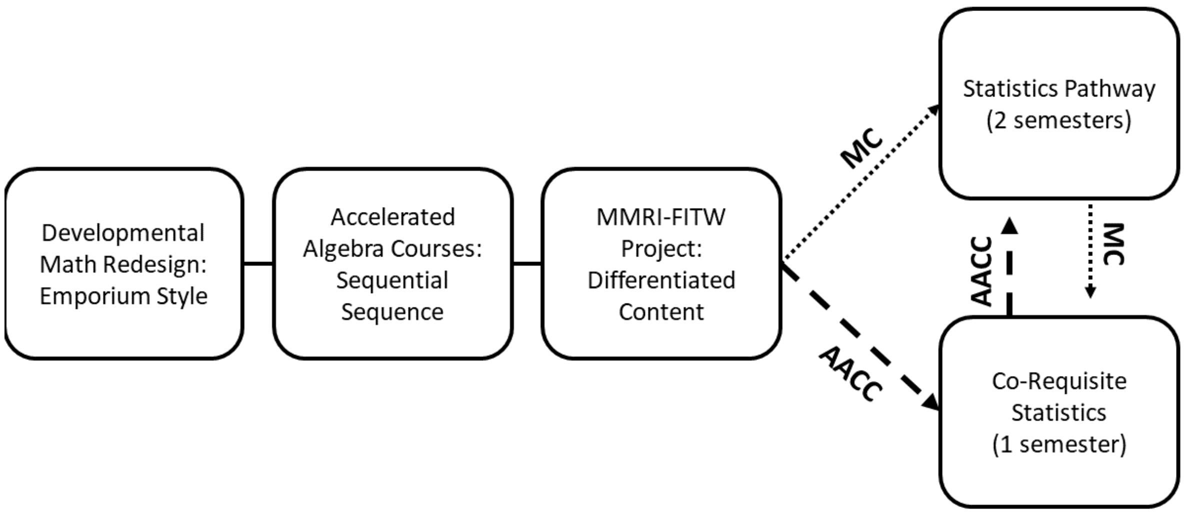


Figure 1-1. Ten years of innovative responses seeking to improve student outcomes in developmental mathematics

Shortly thereafter, both MC and AACC began to incorporate an accelerated model of Intermediate Algebra paired with Introductory Statistics, where the content of both courses was completed in the same semester. The paired course was open to students who placed into Intermediate Algebra (one level below a credit math course), or to students who earned an A or B in the prerequisite, Beginning Algebra. Both courses differentiated algebra content for liberal arts programs of study. The Intermediate Algebra and Introductory Statistics pairing showed promise, as a majority of students at AACC and MC were able to complete the accelerated course in one semester. However, the audience was restricted to upper-level developmental students, and the content required mastery of algebraic topics that did not align with the content of Introductory Statistics.

These early experiences with emporium models and accelerated course pairings were limited in scope and effectiveness because of longstanding Maryland state regulations requiring all college-level general education mathematics courses to be at or above the level of Algebra II (Maryland Higher Education Commission, 2015). In 2015, the state revised the general education provision for mathematics to the following:

One course in mathematics having performance expectations demonstrating a level of mathematical maturity beyond the Maryland College and Career Ready Standards in Mathematics (including problem-solving skills, and mathematical concepts and techniques that can be applied in the student's program of study (COMAR 13B.06.01.03).

These changes supported the MMRI-FITW project, enabling important advances over previous efforts in developmental mathematics reform. Instead of skirting the issue of content alignment, the MMRI-FITW project provided a platform for Maryland colleges to develop a true pathway leading to a general education Introductory Statistics course. The new course requires fewer skills from Intermediate Algebra and can serve as the prerequisite for both Introductory Statistics and Liberal Arts Mathematics. Students in the new pathways course work on the development of algebraic and numerical skills within the context of applications and problem-solving. Topics include quantitative relationships, patterning and algebraic reasoning, functional reasoning, probabilistic and statistical reasoning, incorporating quantitative communication skills, and technology. The pathways course adopted an innovative approach to teaching math and utilized materials from the Dana Center at the University of Texas, Austin. The course structure, content, and pedagogy are aimed at developing the student in a more holistic manner, teaching them how to "be" a math student and to think analytically about the math problems presented in the course. Both institutions embedded this course into the curriculum in different ways; in the following sections, each shares their tale of implementation.

The Two Tales

Anne Arundel Community College

The Maryland Mathematics Reform Initiative-First in the World project provided AACC the opportunity to apply the proven methods of the Dana Center and to re-tool an existing developmental co-requisite option for Introductory Statistics. Prior to changes instituted through MMRI-FITW, Intermediate Algebra was the state requirement for entry into Introductory Statistics. This prerequisite issue forced AACC to closely examine the content in the traditional developmental sequence, reduce redundancies in topics, and select the algebraic topics that best mapped to the learning objectives in Introductory Statistics. A great deal of time was invested in selecting instructors for the course and providing ongoing training each semester in cooperative learning groups, problem-solving techniques, and sharing best practices for teaching the co-requisite content. The emphasis on developing highly skilled instructors became the key to the success in the early co-requisite model. This model has consistently produced above-average success rates since Fall 2014, with 73% of students successfully completing both the algebra-based co-requisite and college level Introductory Statistics in the same semester, compared to 68% who typically succeeded in Introductory Statistics after completing a previous semester of Intermediate Algebra.

In Spring 2016, AACC changed the co-requisite course name to Pre-Statistics and aligned the content to fully support the higher-level concepts of Introductory Statistics. The pre-statistics and introductory statistics courses were first offered together as a co-requisite option in Fall 2016. AACC is already starting to see gains in the overall success rate, with 82% of the students who attempted the co-requisite option completing both Pre-Statistics and Introductory Statistics in the 2016-17 academic year. More importantly, this co-requisite statistics course continues to be extremely effective in eliminating achievement gaps and is the only math course at AACC where the African American and Hispanic students are succeeding at the same rate as the White students—a true testament to the cooperative teamwork among the faculty teaching the course.

By Fall 2017, AACC began offering a new two-semester prerequisite pathways course based upon the Dana Center model. The new prerequisite course, Quantitative Foundations, is a four-hour developmental class covering foundational algebraic and numeric topics, probabilistic reasoning, and graphical interpretation of data—all essential skills in preparing students for Introductory Statistics or Contemporary Mathematics. Broadening the scope of the existing pre-statistics course allowed developmental students a new opportunity to complete credit-bearing mathematics courses in the first two semesters of college, thus ensuring compliance with Maryland's *The College and Career Readiness and College Completion Act* (S. 740 230). The new foundations course serves as an on-ramp to many programs of study at AACC. The new course options had a far-reaching impact on campus, involving every department in re-examining the math requirements for their respective degree and certificate programs. Additionally, they made catalog changes as needed to include one of the new course options, whether co-requisite or pathway, to Introductory Statistics.

Montgomery College

Prior to the MMRI-FITW call for proposals, Montgomery College had already offered the course Intermediate Algebra for Liberal Arts. While the course covered general content that develops skills sufficient to be successful in multiple courses, the MMRI-FITW project provided the Math Department an opportunity to create a new pathways course with content aligned specifically with Introductory Statistics. In Fall 2016, Montgomery College began to offer Foundations of Mathematical Reasoning as a preparatory course for either Mathematics for Liberal Arts or Introductory Statistics, and the data show that it is excellent at preparing students for Introductory Statistics. In Fall 2016, 79% of students who completed the course and then went on to take Introductory Statistics were successful, whereas only 66% of students who completed Intermediate Algebra for Liberal Arts and then attempted Introductory Statistics were successful. These findings suggest that the content and delivery of Foundations of Mathematical Reasoning are preparing students to be successful in Introductory Statistics.

In 2016 a group of math faculty was charged with revisiting the structure of the first two semesters of the developmental math program. Initially, the group worked independently of the MMRI-FITW project. However, within a year their role expanded to a consideration of the design of the developmental math program as a whole and they eventually grappled with the implications of the work that resulted from MMRI-FITW. The workgroup realized that the new pathways course altered the curricular ecosystem in such a way that suggested the possibility of accessing credit math classes very differently. The institution considered not only the structure and pedagogy of the traditional developmental course sequence but the content as well. Later in the process, after participating in a Dana Center-sponsored workshop, the workgroup led a back-mapping exercise. Small groups of faculty representing each of the entry-level credit-bearing math courses compiled lists of the specific prerequisite skills needed to master the outcomes of their respective courses. These lists of foundational skills would form the basis for the incorporation of a pathways approach throughout the math curriculum. Engagement with the pathways course also led to a consideration of the content alignment in the paired Intermediate Algebra and Introductory Statistics course and this ultimately led to the creation of new co-requisite courses for each of the non-STEM math foundational courses where the objectives are closely aligned with the skills required for success.

In addition to course design, there were several other challenges to address in order to ensure the success of the new curriculum. For example, the Math Department could no longer offer the support and the statistics content in a single course as it had been doing without impacting students adversely, because the additional contact hours for the support content were not covered by financial aid. This circumstance led to the creation of true co-requisite courses—credit courses linked to support courses taken concurrently. Another challenge involved faculty concerns about the transferability of credit classes in the event that the prerequisite courses changed. As a statewide collaboration, MMRI-FITW was a powerful factor in helping to bring about change because the faculty could point to a place in the existing curriculum where students were not only already accessing a credit math class with a lower prerequisite threshold but they were performing as well or better than their peers who took the traditional algebraic prerequisite course sequence. Moreover, this pathway reflected changes which had been embraced widely by other institutions throughout the state. Students began taking the new co-requisite courses in Fall 2018 and Montgomery College eagerly awaits data to evaluate the success of this new approach.

Next Steps

As higher education considers the changing mathematics landscape, it is important to note that community colleges serve a diverse population of students and require a variety of tools to meet diverse student needs (Cohen, Brawer, & Kisker, 2014). While some institutions approach pathways and co-requisite models as an either/or scenario, the value of offering both should not be understated. Both pathways and co-requisite models provide better alignment of content with programs of study than other developmental course models; co-requisites provide a one-semester option, while the pathways models present a two-semester course sequence. Both can improve student success but may appeal to different student populations. Co-requisite courses can bolster students' confidence because the barrier to credit-level math is removed. At the same time, co-requisite courses might also increase anxiety among students who may not feel ready for credit-level math courses or who may not have the time to commit to a more intensive math course. In this case, a two-semester course sequence may be more appealing for students seeking a less demanding course load. Regardless of the approach, the learning support components complement the content of statistics in ways that are far more beneficial to students than the previous approach based solely on algebra.

Both approaches also require pedagogical shifts. While they did not require a sacrifice in rigor, they do require significant investment in faculty professional development and training. Both AACC and MC found the Dana Center pathways approach especially helpful for overcoming resistance to these new techniques. In the first year of implementation, both institutions required all instructors using the pathways materials to meet on a regular basis to discuss student progress and work on course modifications. MC faculty thought that the course improved student learning outcomes, allowing students to develop deeper quantitative reasoning skills, preparing them well for Introductory Statistics. AACC faculty also conducted a focus group with students who had completed the pilot course which provided insights into how to improve the course, such as the need for paper-and-pencil tests.

These curriculum changes have also led to increased collaboration between mathematics departments and academic advisors. Numerous meetings and staff trainings were held to ensure that everyone involved with student registration understood the changes in the math programs. A consistent communications plan was developed, and all new students were directed to see an academic advisor prior to registration. The advising staff worked diligently to inform students about the new math pathway options and determine the appropriate path for their program of study. These efforts are essential for the end goal of helping students to complete a mathematics foundation course during the first year of study.

Professional development and training are especially important as faculty adjust to changes in enrollment patterns. Both Anne Arundel Community College and Montgomery College have experienced significant enrollment increases in their Introductory Statistics courses. At Montgomery College, total enrollment in Introductory Statistics almost doubled from Fall 2016 to Fall 2018 (from 1,096 to 2,063). In 2016, 44% of the students enrolled in gateway math courses were enrolled in Introductory Statistics (versus, e.g., Pre-Calculus or Algebra II), a share that grew to 58% in 2018. The enrollment increases are due, in part, to a conscious effort to include Counseling and Advising in the FITW Project, who are now better equipped to explain to students how courses align with programs of study.

In addition, Anne Arundel Community College and Montgomery College have been pleasantly surprised by the growth in enrollment in these new pathways courses. The higher enrollment is credited to the outstanding work of academic advisors. As enthusiasm for these new approaches spreads, faculty and administrators are now beginning to consider co-requisite redesigns for other general education math courses. Both colleges look forward to studying the impacts on student success and encourage other institutions of higher education—especially community colleges—to consider a dual approach to math education.

References

Cohen, A, Brawer F. and Kisker C. (2014). *The American community college* (6th edition). San Francisco, CA: Jossey-Bass.

Complete College America (2018). Co-requisite remediation: Spanning the completion divide. Breakthrough results fulfilling the promise of college access for underprepared students. Retrieved from http://completecollege.org/spanningthedivide/

Maryland Higher Education Commission (May 2015). COMAR Revisions to General Education Requirements. Retrieved from Memorandum.

National Center for Academic Transformation (2005). The Emporium Model: How to Structure a Math Emporium Advice from NCAT's Redesign Scholars. Retrieved from http://www.thencat.org/R2R/AcadPrac/CM/MathEmpFAQ.htm

The College and Career Readiness and College Completion Act of 2013, S. 740, the 433rd General Assembly. (2013). Retrieved from http://mgaleg.maryland.gov/2013RS/bills/sb/sb0740e.pdf

Task Force on Transforming Developmental Math Education – Mathematics Pathways Subcommittee. (January 2018). *Designing math pathways: Supporting students and increasing opportunities for success.* [Final Report from the Task Force on Transforming Developmental Math Education – Mathematics Pathways Subcommittee.] Retrieved from http://dcmathpathways.org/resources/subcommittee- report-designing-math-pathways-supporting-students-and-increasing

About the Authors

John Hamman is the Interim Chief Analytics and Effectiveness Officer at Montgomery College and co-chairs the Achieving the Dream Data Team. John has been at Montgomery College since 2006, previously serving as a professor, chair and Dean of Mathematics, Statistics and Data Science. John has been active in several organizations outside of the college including Achieving the Dream, the Charles A. Dana Center and the Mathematical Association of America.

Milton Nash is the Acting Dean of Mathematics, Statistics, and Data Science at Montgomery College. He has been with Montgomery College since 2011 and has served as a professor and a department chair. Dr. Nash recently led a team of faculty in redesigning the developmental math curriculum at his institution. These efforts resulted in a corequisite curriculum that enables most students to earn a math credit in a single semester. Born in Detroit, Michigan and raised in

Birmingham, Alabama, Dr. Nash is a product of public schools and was a first-generation college student. He would go on to earn a BS degree from the University of Alabama at Birmingham, an MA from Princeton University, and a Ph.D. from the University of Georgia. All degrees were in mathematics. He resides in Alexandria, Virginia with his wife Dr. Monya Ruffin-Nash who is a program director at the National Science Foundation.

Beth O'Reilly is an Associate Professor of Mathematics at Anne Arundel Community College. Her primary focus is improving student engagement and success in online mathematics courses. Currently, she serves as the STEM Core Coordinator helping students to accelerate through the Calculus sequence and advance into STEM degree programs.

Darren Smith currently serves as the Department Chair of Mathematics, Statistics, & Data Science on the Germantown Campus of Montgomery College. He has worked in close collaboration with the First in the World - Maryland Math Reform Initiative (FITW-MMRI) Project helping to develop and coordinate the Pre-Statistics course offering. He holds an MS in Mathematics Education.

Robyn Toman is a Mathematics Professor at Anne Arundel Community College. For twenty years, she has been involved in improving the developmental mathematics pathways for community college students and has been active in state-side reform. She is currently coordinating a program with the local school system to enhance the mathematics college readiness of high school graduates.

While at Montgomery College, ***Bess Vincent*** served as an Assistant Administrative Dean and as an institutional lead for the First in the World - Maryland Math Reform Initiative (FITW-MMRI) Project. Currently, she works at Johns Hopkins University as the Director of Special Projects for the Krieger School of Arts and Sciences. She holds a Ph.D. in Sociology from Tulane University.

Chapter 2

How a Statewide "Nudge" Became a Call to Action in One Mathematics Department

Felice Shore[3]

Towson University

Abstract

This paper describes the impact that involvement in a statewide grant project had on Towson University's Department of Mathematics. After a brief history of the department's policies and practices around math placement and developmental coursework prior to joining the First in the World efforts, an account of the department's work spurred by project participation follows. Foremost, the department moved away from offering students only a singular track of algebra-based preparation for early college mathematics courses in favor of establishing a second, non-algebra intensive, mathematics pathway. This pathway was most intentionally designed to prepare students for—and expedite completion through—introductory statistics. Additionally, creation of the two pathways resulted in putting a spotlight on other long-standing practices. This led the department to reconsider policies around initial course placement, course sequences to Calculus, and coordination of and extra-classroom support for large-enrolled courses, namely Basic Statistics.

---

[3] Corresponding author: fshore@towson.edu

Towson University's response to the University System of Maryland's (USM) Maryland Mathematics Reform Initiative project, funded by a First in the World grant (MMRI-FITW) led to fundamental changes in policy and curriculum implemented by the Department of Mathematics. Our overarching goal was to improve the early experiences in mathematics for our undergraduate students, particularly those in majors that do not require an algebra-intensive course sequence. This paper describes the distinct but interconnected tentacles that grew out of our FITW participation.

Context: Towson University's Practices Prior to MMRI-FITW

For at least several years prior to the Mathematics Department's involvement with MMRI-FITW, our practices around placement into mathematics courses, as well as what pre-requisite courses constituted "developmental" (thus, non-credit bearing) course work, had been evolving. The changes we implemented at different times and their rationales mirrored national concerns and complexities around the analysis of developmental education's efficacy and goals. Nationally, the outcomes of students relegated to developmental courses are concerning. At four-year schools, roughly one-third of students take developmental math and only 58% of those students complete all of their developmental math requirements (Chen, 2016).

At Towson, our situation has not been as dire. First, around 2011, we changed the designation of one particular math course from "developmental" to credit-bearing, with the caveat that it would only serve as a prerequisite to general education math requirements. The decision, supported by a majority of the department, was bolstered by the fact that there was precedent for this at other schools in USM—and that reflected, if tacitly, the fact that there are disagreements about what knowledge or skill level constitutes "college readiness" in the first place (Bailey, et al., 2010). Furthermore, some in the department maintained that awarding credit could mitigate the demoralization students mis-assigned to remediation feel in non-credit courses, an effect documented in the literature (Scott-Clayton & Rodriguez, 2015). Secondly, prior to 2014 at TU, only students with SAT scores below 500 were required to take a standardized placement test (ACCUPLACER), and it was used only to determine if they needed algebra preparation before *any* general education courses or not; it did not determine placement into various levels of general education courses. During that time, fewer than 20% of freshmen were placed into either the developmental or gateway courses, and within those courses, pass rates ranged from about 70-84%.

A major shift came in 2014, when the department instituted a mandatory placement test for *all* incoming freshmen (and some transfers), whose cut scores would be used not only to place them into developmental or gateway courses but also to determine eligibility for the variety of general education courses up through Calculus I. The rationale for this decision was a general sense in the department that students were often underprepared for the courses in which they were placed based on determinants used by the Advising Office, such as high school course work. The purpose for the test required a change of test altogether, specifically one that could be administered online and remotely. A committee of math faculty chose tests constructed by the Mathematical Association of America (MAA) and established cut scores by comparing TU courses to courses at another school that used those same MAA tests.

Throughout the placement policies described above—and despite the fact that we could manipulate the numbers of students who ended up in developmental or gateway courses by simply shifting cut scores—students who scored on the low end of our placement scale were relegated to a hierarchical sequence of algebra preparation. This singular preparation stream was required no matter what course a student needed to satisfy the general education or their specific major's math requirement. As a way to shorten completion time and/or improve retention, the idea of bucking that status in favor of separate "math pathways" had already gained traction in higher education around the country by 2010. In particular, the Dana Center at University of Texas championed a *statistics* pathway, and the California Acceleration Project began supporting similar efforts among that state's two-year colleges as well (see for example, Hern, 2012).

In 2015, influenced by the work of the Dana Center's Mathematics Pathways, USM called for college and university partners to join their FITW project, whose goal was to create a statistics pathway that, for many students, would reduce the time to completion of college-level mathematics. As a mathematics educator whose research focus had been in statistics education, I was the natural choice for the candidate to lead the project at Towson University. Additionally, I had spent the first 12 years of my career as a faculty member at an urban community college, an experience which was formative for me. Although once at Towson, I had not taught the developmental or gateway courses, I was well aware of the dispositions of students in those courses and had long lamented the disconnect between developmental course content and that of the courses approximately half of all students in them would ultimately need.

The following sections describe the various components of our FITW work. They are brief by design, intended to convey an overview of how and why they developed.

A Tale of Two Pathways

I led a small committee of Mathematics Department faculty in a close examination of our current course sequences, particularly those starting from the lowest level and leading to our introductory statistics courses. The examination revealed inconsistent policies whose rationales either no one could recall or were arguably questionable. For example, *Figure 1-1* depicts the original sequences to two different introductory-level statistics courses in our department (Basic Statistics and Bio Statistics). Placement test scores determined eligibility for courses along the path shown. Two consequences are notable: (1) Basic Statistics, which is slightly less demanding than Bio Statistics, had a higher-level prerequisite course, and (2) some students had a steep hill to climb before gaining entrance to Basic Statistics, potentially having to complete three prerequisite courses at TU. While not evident in the figure, the shortcoming most targeted by FITW work was that neither statistics course relied on students having mastered more than a fraction of the specific skills in all of those pre-requisite courses.

Our first major decision in reorganizing our prerequisites was to settle on no more than two preparation tracks. Two tracks would provide appropriate mathematics preparation for the variety of entry-level math coursework required for different majors, while avoiding overburdening resources like classrooms and faculty. It seemed obvious that the most important distinction between our general education courses was the level of algebra preparation they expected. Considering the mathematics requirements of our various majors, the most sensible designation that emerged for our two pathways (into which *courses*, not majors, are sorted) was either "algebra-intensive" or "non-algebra-intensive." A result of this policy meant that some of our majors (e.g., business and nursing) would require courses in both pathways. Students in those particular majors who place below readiness for the first general education algebra-intensive course would take the preparation courses in the algebra-intensive pathway, which would also serve as acceptable (albeit less relevant) preparation for their required non-algebra-intensive course, typically Basic Statistics.

Whereas Basic Statistics and Mathematical Ideas (our version of math for liberal arts) were more easily identified as non-algebra-intensive, we had to weigh a variety of competing factors to classify other math courses as such. In creating the pathways, other department members renewed their efforts to ensure that the sequencing of courses in the algebra-intensive pathway to calculus made sense. The examination resulted in a significant change in the status of Finite Math, moving from an acceptable pre-requisite for our business calculus course to a terminal course in the non-algebra pathway. The graphic depiction of our finalized pathways appears at the end of this chapter (see Appendix A). Thus, the work of the FITW grant foremost prompted a reorganization of course sequences into an algebra-intensive pathway and a non-algebra-intensive pathway, and motivated the creation of the new pre-requisite course for the latter.

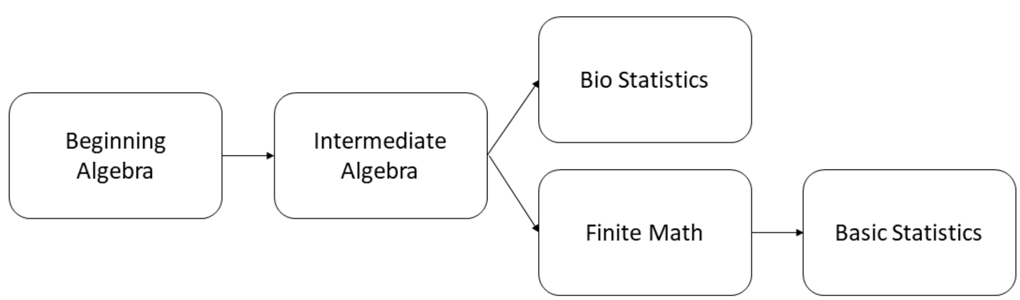


Figure 2-1. Course sequence example prior to reorganization

Selecting and Implementing the Pre-Statistics Course

The first major task after signing on to the mission of FITW and creating the pathway structures was the establishment of the course that would serve as preparation for the non-algebra-intensive general education courses, Foundations of Mathematics Reasoning (MATH 100; hereafter "Foundations"). Foundations would replace either one or two courses (depending on placement score) that had previously been required for students whose placement score was not high enough to enter the general education courses. A white paper by Peck and colleagues (n.d.) entitled *Mathematics Prerequisites for Success in Introductory Statistics* provided a mapping between mathematical skills in statistics and their prerequisite skills. We compared those prerequisite skills to the mathematical demands of TU's other non-algebra intensive courses and found an adequate match.

We chose the Dana Center's "Foundations of Mathematical Reasoning" curriculum because of its context-rich, activity-based approach to teaching the relevant prerequisite skills for Basic Statistics (as well as the other non-algebra-intensive courses). FITW funding has allowed us to compensate our Foundations instructors (all adjuncts) to continually review and revise the course and materials since its inception. Foundations instructors have reported some challenges with the current curriculum materials. First, the student materials seem lacking in instructional detail for students who are not able to extract such information from their activity work on their own. Additionally, teachers of this course must buy into the active learning pedagogical approach and be able to facilitate the non-traditional lessons. For a department that depends on adjuncts to teach this course, the latter challenge could present a sustainability issue. A course coordinator leads these review and revision efforts and liaises with faculty of courses for which Foundations serves as preparation. The coordinator's current focus is to identify and consider alternative course materials to address the concerns that have been raised.

Reconsidering Placement

The creation of the pathways and new prerequisite course led TU's Mathematics Department to reconsider the effectiveness of our math placement process and exam. As faculty began ongoing work to improve the alignment of content between consecutive courses in the algebra-intensive pathway, some faculty were skeptical that our current placement process could distinguish between student readiness for the different courses in either pathway, especially among the algebra-intensive courses. Our placement process also did not offer a mechanism for students to have a meaningful review of content, which could help students distinguish material they had once learned but forgotten from content they had never learned. In response to aforementioned concerns about the placement test, the department ultimately adopted ALEKS PPL as the new placement assessment, implemented for Fall 2018 incoming students. Although TU arrived at that decision independently, other USM schools were considering ALEKS PPL during approximately the same time frame, in part because of its adaptive technology and provision for individualized review.

While we believe the newly adopted placement system offers improvements over the previous system, we acknowledge the limitations of and questionable efficacy inherent in using a single exam score for placement (Burdman, 2015). As a department, we are in general agreement that the goal is to enroll students into the highest course in which they have a reasonable chance of success. However, what grade outcome constitutes "success" and what probability constitutes "reasonable chance" are elusive, given differences in program requirements and consequences of incorrect placement, respectively (Scott-Clayton, Crosta, & Belfield, 2014). Therefore, we continue to investigate ways to implement potentially more accurate placement procedures. Although our department does not currently use an algorithm employing multiple measures to suggest course placement, we nevertheless consult with TU's Advising Office on many cases in which we consider multiple data points on a student's record (e.g., standardized test scores, high school or other college coursework, high school or other college GPA, etc.).

Because of our recent attention to placement issues, a faculty member in our department created a research opportunity for undergraduates in which he led a project exploring how regression trees might be used to identify the most influential variables for predicting success in in our Pre-Calculus course. Their first iteration used data that included scores on our *former* placement test. Not surprisingly, preliminary results revealed that the (old) placement score was among the weaker predictors of students' ability to pass the course. High school GPA was by far the strongest predictor of both passing the course and earning the grade of B or higher in the course, a finding corroborated in the literature (see for example, Scott-Clayton et al., 2014). Scores on standardized tests (including the SAT and our placement exam) were the next strongest predictors, followed by demographic characteristics. The department is currently examining how well the cut scores on the new placement test (ALEKS) align with student success at the end of our courses.

Until recently, and because of the algebraic focus of standard placement tests, the cut score for entry into introductory statistics courses was likely higher than it needed to be (in terms of the particular algebraic skills it required). In a sense, knowledge of algebra served as a sort of proxy for a level of mathematical maturity expected in not only statistics, but other non-algebra intensive courses as well, for example, in a mathematics course for pre-service elementary teachers. Though not well defined to begin with, "mathematical maturity" is described differently depending on the particular stage of a learner's mathematical development (Garrity, 2014). Even at different levels, however, common traits are the ability to think flexibly, communicate about mathematical concepts, and recognize that mathematics should makes sense, i.e., seeing the interconnectedness of mathematical ideas without being strictly tied to isolated facts and skills (see, e.g., Faulkner et al., 2017; Garrity, 2014; Hare & Phillippy, 2004).

Certainly, there is a set of basic mathematical skills needed for success in introductory statistics, identified through content analysis (Peck, Gould, & Utts, n.d.) and research on predictors of success in the course (Johnson & Kuennen, 2006). A realistic placement practice would lower the test cut score to better match those skills, and that is precisely what our department did. However, that placement practice still fails to address the issue of assessing "mathematical maturity." I argue that the practice of using standard mathematics placement tests—however the cut score is established—to assess readiness to engage with many of those conceptually challenging ideas in statistics remains questionable. We continue to grapple with this concern.

Reform of our Introductory Statistics Course

Our participation in MMRI-FITW put a spotlight on Towson's introductory statistics course, MATH 231: Basic Statistics. It is the department's largest course, each semester serving 650-750 students (across 22-26 sections) from a wide variety of majors. With attention on—and FITW funding support for—Basic Statistics, we engaged in several initiatives, described below, namely (1) providing outside-of-class support, (2) realigning instruction across course sections, and (3) seeking course leadership. The first of those efforts unintentionally provided the impetus for the others, consequently culminating in a major overhaul in the content and implementation of Basic Statistics.

Outside-of-Class Support

In Spring 2017, several math faculty members collaborated to pilot an extra-classroom support program using a Peer-Led-Team-Learning (PLTL) approach. In PLTL, students voluntarily attend weekly sessions led by "coaches" (successful Basic Statistics students from the previous semester) who facilitate collaborative learning activities. PLTL has been used in STEM disciplines extensively as a model of extra support (see meta-analysis by Wilson & Varma-Nelson, 2016). Positive outcomes for mathematics include improved understanding of content (Merkel & Brania, 2015) and better attitudes toward the subject (Curran, Carlson, & Celotta, 2013). For a more complete description of the PLTL pilot program and outcomes, see Chart et al. (2018).

In the pilot semester, as one of the faculty members involved, my task was to create activities and then train the coaches to implement them the following week in their sessions. Feedback from coaches hinted at a large problem that had previously gone undetected by the department: considerable course "drift"; i.e., different instructors covered different topics, in different orders, and seemingly to different levels of rigor. In short, the course was not uniformly taught. This feedback presented serious challenges to the PLTL structure, which depended on students being in roughly the same place in the course each week. In order to verify and document the extent of the problem, as well as begin to address it, an instructor was enlisted to assist me in performing certain functions which might typically be assigned to a course coordinator. Those efforts are described in the next section. The PLTL program has continued through subsequent semesters, necessarily evolving in both content and structure per revelations about—and ultimately changes to— Basic Statistics, as described below.

Coordinator Activities: Getting a Handle on a Course Adrift

In Summer 2017, supported by FITW funding, the temporary coordinator and I worked together to take stock of similarities and differences between sections taught by about 13 different instructors (depending on semester), the vast majority of whom were adjuncts. We surveyed instructors on which specific topics they covered and how they covered them; collected syllabi and exams to compare topic sequencing, general course expectations, and rigor; and compared grade distributions. Despite the dissemination of a departmental course outline that instructors were expected to follow, the results of the survey clearly pointed to a course that delivered vastly different experiences to students, depending on their instructor. The failure rates (grades of D, F, and W) ranged from 0-65% across sections.

An additional and consequential finding was that Basic Statistics, in both its content focus and pedagogical approaches, was incongruent with recommendations of the American Statistical Association's GAISE report (2016). For example, the GAISE report included a list of topics to consider omitting from an introductory statistics course. Our course still included content and skills on that list, for example, probability theory and drilling students in using statistical tables. GAISE's six affirmative recommendations included focusing on conceptual understanding, fostering active learning, and using technology to explore concepts and analyze data, among others. However, from our collection of instructors' artifacts and an examination of course materials, whether these practices were employed in any consistent manner, if at all, was arguable at best.

Change in Curriculum and Establishment of Consistent Leadership

During academic year 2017-18, I took on a limited role as acting-coordinator for Basic Statistics and in that capacity began communicating clearer directives to the instructors about which topics to cover, in what depth, and in what sequence. Simultaneously, a thorough text review commenced in search of course materials that paid more than lip service to putting GAISE recommendations into practice. Ultimately, a curricular program was selected whose approaches met that goal.[4] A full day of training for instructors took place in late spring, 2018. Another significant achievement occurred when the Department hired a permanent lecturer to take on the role of course coordinator. Thus, beginning Fall 2018, Basic Statistics had dedicated leadership. That leadership, together with a substantively new content approach to the course, provides reassurance that students across sections will have more similar and conceptually-focused experiences in Basic Statistics.

Conclusion

Towson University's Mathematics Department undertook myriad initiatives as a participant in the USM's MMRI-FITW grant project to improve student's early

[4] TU chose Lock et al. (2017) which uses a simulation-based inference approach to teach the logic of statistical inference. Its pedagogical slant, demonstrated by supplemental materials, encourages active learning strategies.

experiences in mathematics. This is especially true for students whose program requirements are not algebra-intensive and who present with additional mathematics instructional needs upon enrollment. The department's endeavors described above point not only to the grant's direct influence on the non-algebra-intensive pathway, and particularly on statistics, but also the fortuitous effects MMRI-FITW had on the algebra-intensive pathway: As our work to improve students' experiences to and through introductory statistics progressed, parallel work to shore up the algebra-intensive course sequences to the calculus courses ensued. The far-reaching impact of the Maryland Mathematics Reform Initiative and First in the World grant on Towson University's Mathematics Department should not be understated.

References

American Statistical Association (2016). Guidelines for Assessment and Instruction in Statistics Education (GAISE) College Report 2016. Retrieved from http://www.amstat.org/education/gaise.

Bailey, T., Jeong, D.W., & Cho, S. (2010). Student progression through developmental sequences in community colleges. *CCRC Brief, 45*, 1–6. Retrieved from https://files.eric.ed.gov/fulltext/ED512395.pdf

Burdman, P. (2015). Math placement tests deserve more scrutiny. *EdSource.* Retrieved from: https://edsource.org/2015/math-placement-tests-deserve-more-scrutiny/90132

Chart, S., Kara, M., Shore, F. & Spitzer, S. (2018). Examining the effectiveness of a support model for introductory statistics. In *Proceedings of the XXI Annual Conference on Research on Undergraduate Mathematics Education*.

Curran, E. M., Carlson, K., & Celotta, D. L. T. (2013). Changing attitudes and facilitating understanding in the undergraduate statistics classroom: A collaborative learning approach. *Journal of the Scholarship of Teaching and Learning, 13*(2), 49–71.

Faulkner, B. E., Herman, G. L., & Earl, K. (2017). Engineering Faculty Perspectives on Student Mathematical Maturity. *Proceedings of the ASEE Annual Conference & Exposition*, 4147–4156.

Garrity, T. (2014). Using mathematical maturity to shape our teaching, our careers, and our departments. *Notices of the AMS, 58*(11), 1592–1593. Retrieved from https://www.ams.org/journals/notices/201111/rtx111101592p.pdf

Hare, A., & Phillippy, D. (2004). Building mathematical maturity in calculus: Teaching implicit differentiation through a review of functions. *The Mathematics Teacher, 98*(1), 6–12.

Hern, K. (2012). Acceleration across California: Shorter pathways in developmental English and math. *Change: The Magazine of Higher Learning, 44*(3), 60–68. https://doi.org/10.1080/00091383.2012.672917

Johnson, M & Kuennen, E. (2006). Basic math skills and performance in an introductory statistics course. *Journal of Statistics Education, 14*(2). doi: 10.1080/10691898.2006.11910581

Merkel, J. C., & Brania, A. (2015). Assessment of peer-led team learning in Calculus I: A five-year study. *Innovative Higher Education, 40*(5), 415–428.

Peck, R., Gould, R., & Utts, J. (n.d.). *Mathematics prerequisites for success in introductory statistics*. [Statement]. Retrieved from http://dcmathpathways.org/sites/default/files/resources/2017-05/Math%20Prerequisites%20for%20Success%20in%20Intro%20Statistics_20170515.pdf

Scott-Clayton, J., Crosta, P., & Belfield, C. (2014). Improving the targeting of treatment: Evidence from college remediation. *Educational Evaluation and Policy Analysis, 36*(3), 371–393.

Scott-Clayton, J. & Rodriguez, O. (2015). Development, discouragement, or diversion? New evidence on the effects of college remediation policy. *Education Finance and Policy, 10*(1), 4–45.

Wilson, S. B., & Varma-Nelson, P. (2016). Small groups, significant impact: A review of peer-led team learning research with implications for STEM education researchers and faculty. *Journal of Chemical Education*, 93 (10) 1686–1702. Retrieved from https://pubs.acs.org/doi/full/10.1021/acs.jchemed.5b00862

About the Author

Felice Shore has a Ph.D. in Curriculum and Instruction, with specialization in Mathematics Education, from the University of Maryland. She is a Professor and Assistant Chair in the Mathematics Department at Towson University. Her teaching and research interests straddle two distinct areas: introductory statistics and mathematics content and methods for elementary and middle school teacher preparation programs. She co-authored two research publications in the Journal for Statistics Education as well as several papers in teacher education practitioner journals. As the institutional leader on the First in the World Grant, she has been teaching introductory statistics while spearheading the reform of that large service course at Towson University.

Chapter 3

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

Caitlin Kowalewski[5]

University of Maryland, Baltimore County

Liz Stanwyck

University of Maryland, Baltimore County

William R. LaCourse

University of Maryland, Baltimore County

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.

[5] Corresponding author: caitkow1@umbc.edu

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[6] (Fry, 2017). As of 2017, 47.76% of Americans age 25-46 had completed a tertiary level of education[7] (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

[6] The OECD definition of college attainment is the percentage of 25- to 34-year-olds completing at least an associate degree.

[7] "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.

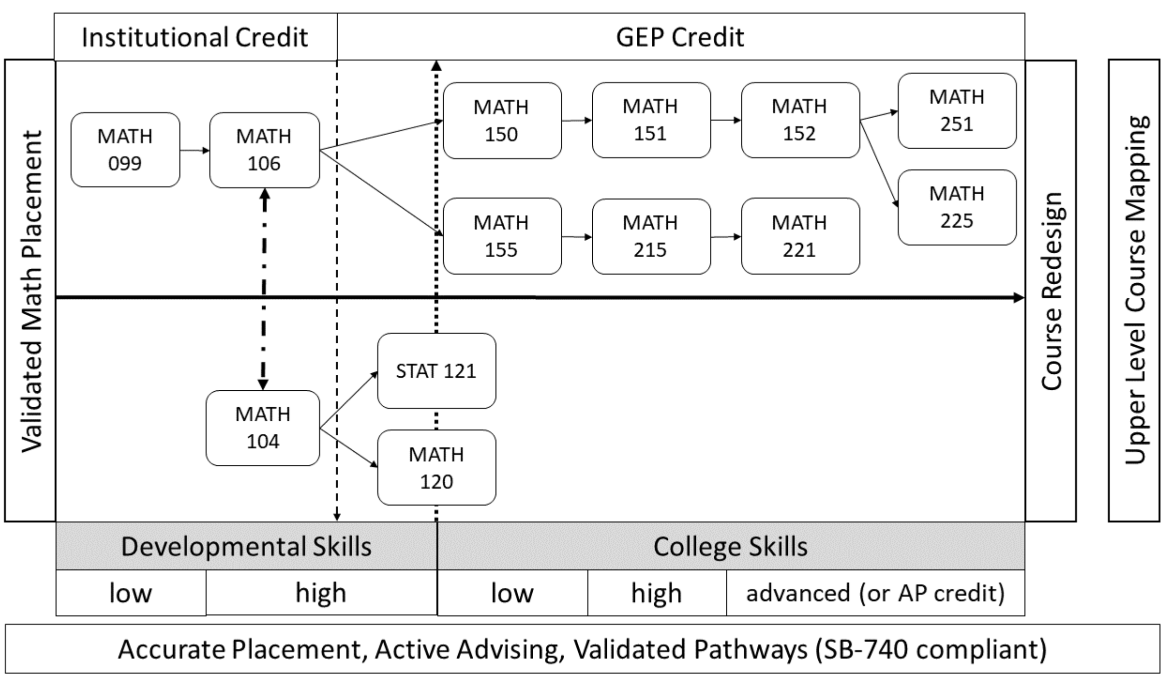


Figure 3-1. Mapping of math pathways and placement at UMBC

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® 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® 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.

References

Center for Community College Student Engagement. (2016). *Expectations meet reality: The underprepared student and community colleges.* Austin, TX: The University of Texas at Austin, College of Education, Department of Educational Administration, Program in Higher Education Leadership. Retrieved August 10, 2018 from https://www.ccsse.org/docs/underprepared_student.pdf.

Organisation for Economic Co-operation and Development. (2019).Population with tertiary education (indicator). doi: 10.1787/0b8f90e9-en. Retrieved August 10, 2018 from https://data.oecd.org/eduatt/population-with-tertiary-education.htm

Fry, R. (2017, January 18). U.S. still has a ways to go in meeting Obama's goal of producing more college grads. Retrieved from http://www.pewresearch.org/fact-tank/2017/01/18/u-s-still-has-a-ways-to-go-in-meeting-obamas-goal-of-producing-more-college-grads/

Maryland Higher Education Commission. (2013). *Maryland ready: 2013-2017 Maryland state plan for postsecondary education*. Retrieved August 10, 2018, from https://mhec.maryland.gov/institutions_training/Documents/acadaff/acadproginstitapprovals/MHECStatePlan_2014.pdf

Campbell, J. R., Voelkl, K. E., & Donahue, P. L. (2000). *NAEP 1996 trends in academic progress, NCES 97–985r.* [Report for U.S. Department of Education, Office of Educational Research and Improvement, National Center for Education Statistics.] Washington, DC: U.S. Department of Education.

Snyder, T. D., de Brey, C., & Dillow, S. A. (2016). *Digest of education statistics 2015 (NCES 2016–014).* [Report for U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics.] Washington, DC.: U.S. Department of Education. Retrieved from https://nces.ed.gov/pubs2016/2016014.pdf

Steen, L. A. (ed.) (2001). *Mathematics and democracy: The case for quantitative literacy.* Princeton, N.J.: Woodrow Wilson Foundation National Fellowship Foundation. Retrieved August 10, 2018 from https://www.maa.org/sites/default/files/pdf/QL/MathAndDemocracy.pdf

UMBC research fast facts. (n.d.). Retrieved May 5, 2019 from https://research.umbc.edu/fast-facts/.

U.S. Census Bureau. (2017). QuickFacts: Maryland. Retrieved September 17, 2019 from https://www.census.gov/quickfacts/MD

Welcome to UMBC. (n.d.) Retrieved August 10, 2018 from https://about.umbc.edu/.

What is ALEKS® PPL? (n.d.) Retrieved August 10, 2018, from https://www.aleks.com/highered/ppl/what_is_aleks_ppl

About the Authors

Caitlin Kowalewski is the Research Coordinator for the College of Natural and Mathematical Sciences (CNMS) at UMBC. She holds a master's degree in Applied Molecular Biology, and currently helps to coordinate several educational initiatives under CNMS. She is also an instructor of introductory biology and microbiology courses, and has designed curriculum for several courses in the biological sciences. Caitlin primarily likes to focus on mentoring students and developing educational reforms that increase student success and learning.

Liz Stanwyck is a Senior Lecturer in the Department of Mathematics and Statistics at UMBC. She is passionate about teaching and advising all levels of undergraduate students, and especially enjoys finding new ways to help students become self-sufficient learners. Liz seeks opportunities to collaborate with colleagues across academic disciplines and learn from different perspectives.

William R. LaCourse is Dean of the College of Natural and Mathematical Sciences (CNMS) and Professor of Analytical Chemistry at UMBC. In 2005, he established UMBC's Chemistry Discovery Center, which dramatically improved student performance in introductory chemistry courses. Dr. LaCourse also oversees the College Active Science Teaching & Learning Environment (CASTLE) and the Science Learning Collaboratory. He works with his colleagues to develop and implement an ambitious strategy for the advancement of the educational and research mission of the CNMS. In addition to his administrative experience at the University level, Dr. LaCourse conducts research on hydrodynamic electroanalytical techniques in chromatographic and electrophoretic systems, which has resulted in 111 publications, including 20 chapters and a sole-authored book entitled Pulsed Electrochemical Detection in High Performance Liquid Chromatography, and two issued patents.

Chapter 4

PROBLEM-SOLVING MODEL AND APPLICATIONS TO REAL LIFE: DEVELOPMENT OF AN ALTERNATIVE STATISTICS PATHWAY

Margo Coleman-Seiffert[8]
Department of Psychology, University of Maryland Global Campus

Elizabeth Mulherrin[9]
Curriculum and Programs, University of Maryland Global Campus

Abstract

This chapter describes one university's approach to developing an online statistics pathway course designed to prepare undergraduate students to develop the mathematical and statistical thinking skills needed for success in college and the workplace. A needs analysis was conducted with department chairs from a variety of academic disciplines to determine the relevant mathematical and statistical competencies needed by students to be successful in their programs. The recommendations derived from the needs analysis aligned with the 2016 American Statistical Association's guidelines, emphasizing statistics "as an investigative process of problem-solving and decision-making" (GAISE, 2016, p. 3) that may enhance student motivation to learn and understand statistics. A three-step problem-solving model and real-life applications of concepts were incorporated into the course to increase student engagement, metacognition, and transferability of skills. Institutions considering a more holistic approach to teaching quantitative concepts may find that surveying relevant stakeholders helps to identify the specific needs of their students, and that emphasizing an approach of problem-solving and application of concepts in real-life contexts may increase the relevance of statistical thinking for students to their education and careers.

---

[8] Corresponding author: Margo.Coleman-Seiffert@faculty.umuc.edu
[9] Corresponding author: Beth.Mulherrin@umuc.edu

The purpose of this chapter is to describe the process employed in one university mathematics department to develop a foundational mathematics course that uses a holistic pedagogical approach designed to enhance students' metacognition and demonstrate the relevancy of mathematical and statistical thinking to work in college and careers. This holistic approach emphasizes preparing undergraduate students to apply practical concepts and critical thinking skills and enhancing their motivation to learn and understand statistics. These aims align with the 2016 American Statistical Association's (ASA) guidelines for instruction that characterize statistics "as an investigative process of problem-solving and decision-making" (GAISE College Report ASA Revision Committee [GAISE], 2016, p. 3).

The Maryland Higher Education Commission (MHEC) revised the general education requirements for college-level math in 2016 to include a broader focus on quantitative reasoning, reflecting the 21st-century knowledge and skills that students need to succeed in college and in the workplace. There is a growing recognition that quantitative literacy and statistics may be more career-relevant than the traditional college-level algebra pathway for students in some disciplines, particularly those in non-STEM fields (Charles A. Dana Center, 2015; Morgan, Hall, & Shapiro, 2019).

Background

In 2016, the University of Maryland University College (UMUC) created Foundational Mathematics, a new *preparatory* statistics course (sometimes called "developmental," or below the level of a general education course and not eligible for transfer credit), with the goal of preparing students for an *introductory* statistics course, in lieu of a college-level algebra requirement for some majors. The mathematics foundation course was developed as part of the statewide Maryland Mathematics Reform Initiative (MMRI), made possible by a First in the World (FITW) grant, to develop new math pathways. The MMRI-FITW grant coincided with a UMUC initiative to redesign the undergraduate introductory statistics course to enhance the relevance of statistics for our students and better integrate the demands of the academic programs that had statistics as part of their degree requirements. The design process of the new mathematics foundation course was coordinated with the redesign process of the introductory statistics course.

In this chapter, we provide background information about our students and the impetus for redesigning the statistics pathway. We then describe the process used for designing the new mathematics foundation course and redesigning the introductory statistics course, specifically, how the data we gathered for the redesign of the statistics course guided the format and content of the preparatory course, Foundational Mathematics. Next, we discuss the problem-solving approach that we incorporated into the preparatory course to develop critical thinking skills in mathematics, statistics, and, potentially, other subject areas. Finally, we describe and provide an example of a "real-life application" (that is, a problem that requires students to apply concepts learned in order to solve realistic, data-based scenarios) that helps students understand the relevance and applicability of the mathematical concepts they are learning.

For many students, there is a disconnect between course content and the skills they need to be successful in their professional and personal lives, particularly for adult learners for whom high-school math is a distant memory. One particular challenge is helping students see the relevancy of statistics and math concepts to their personal and professional lives. Another challenge is helping students to develop overarching critical thinking skills—"to think about how to think"—and not focus solely on solving a given mathematical or statistical problem.

Discussion

Insight into Teaching Statistics and Prerequisite Statistics Skills at UMUC

UMUC is an open university, serving working adults, military servicemembers and their families, and veterans who reside in Maryland, across the United States and around the world. UMUC offers eight-week courses, many offered solely online, taught by full-time and adjunct faculty. The median age of stateside UMUC undergraduate students is 30, with more than 75% percent working full-time (University of Maryland University College, 2018).

While UMUC students bring a wide range of practical real-life experiences to their courses, they also have some academic readiness challenges, including prerequisite mathematical, critical thinking, and reading skills. Many students postpone taking required math or statistics courses and may experience anxiety about the course material, and therefore may delay in completing assignments. In addition, since many students lack the prerequisite math skills needed to place into the introductory statistics (or other college-level math) course, they must take one or more foundational mathematics courses. Prior to UMUC's course redesign efforts associated with MMRI, these foundational mathematics courses were the same regardless of whether the student was a non-STEM or STEM major.

The capacity to transfer current knowledge, skills, and abilities, including the ability to take different perspectives on solving problems, is important to help students when encountering difficult or unfamiliar material; these abilities can also assist students in learning from one another. To better address the needs of our diverse student population, UMUC incorporated a specific problem-solving approach and the application of statistical concepts to real life situations into preparing undergraduates for introductory statistics, which will be described in the following sections.

Needs Analysis for the Introductory Statistics Course

As noted earlier, the design of the new foundational mathematics course coincided with the redesign of UMUC's introductory statistics course. Prior to its redesign, UMUC's introductory statistics course used a traditional approach which emphasized hand-calculation of statistical formulas. The goals for redesigning the introductory statistics course were to bring it more in line with the GAISE guidelines and to improve student understanding and use of statistics. Since the purpose of the foundational mathematics course is to prepare students for the introductory statistics course, the outcomes of that introductory statistics course guided the development of the new foundations course.

As a precursor to the redesign of the introductory statistics course, the first author conducted a needs analysis with the program chairs from all of the departments that required introductory statistics as part of their major programs. The program chairs identified the statistical competencies their students need to master to be successful in their courses and programs, as well as in future careers in their major field. Both quantitative and qualitative information were collected and analyzed. The needs analysis was completed using the steps listed in Table 4-1. Steps 4 through 6 are discussed in greater detail below.

Table 4-1. *Needs Analysis Process*

Step	Description
Step 1	Orientation Meeting with Program Chairs *During this meeting, the goals and process of needs analysis were described.*
Step 2	Completion of Surveys on Individual Program Statistical Needs *Program chairs identified the topic areas that their students need for success in specific programs as well as their chosen field of study.*
Step 3	Individual Meetings with Program Chairs *During these meetings, program chairs identified specific statistical concepts and desired student outcomes.*
Step 4	Data Analysis *The quantitative data from surveys and qualitative data from interviews were analyzed.*
Step 5	Development of Recommendations for the Introductory Statistics Course
Step 6	Dissemination of Findings and Recommendations to Program Chairs, and Solicitation of Feedback

Data analysis. Survey results were tabulated and showed that most programs required knowledge of the following topics: data collection methods; exploratory data analysis; correlation and linear regression; basic probability (e.g., normal distribution and p-values); sample size and power; type I and type II error; confidence intervals; and one- and two-sample hypothesis testing. We also conducted a theme analysis of the qualitative data obtained in the interviews. Among the results, we found that program chairs desired less focus on computation and greater focus on statistical reasoning, with specific mention of interpretation of results beyond the data and written communication of results. The introductory statistics course should develop students' professional judgment regarding meaningfulness, appropriateness, and accuracy of results. Additionally, program chairs indicated that the use of applications would increase relevancy of concepts, and that students should be trained to use software, such as Excel, to complete calculations.

The results of the needs analysis indicated a need for greater emphasis on statistical reasoning and interpretation skills, use of technology, and real-world applications. These results were also in alignment with the American Statistical Association's guidelines for the teaching of undergraduate statistics courses, which recommend "[focusing] first on *what* to teach in introductory courses and then on *how* to teach those courses" (GAISE, 2016, p. 3).

Development of recommendations for the introductory statistics course. Ultimately, based on the needs analysis and review of the GAISE report, our recommendations for course design and redesign were to (1) streamline the statistics pathway; (2) highlight the concepts identified in Step 4 of the needs analysis; and (3) focus on statistical reasoning, use of technology, and interpretation and communication in the writing of statistical results.

Dissemination of findings and recommendations to program chairs, and solicitation of feedback. Results from the needs analysis were presented to the program chairs, who were provided with the opportunity to give feedback. The program chairs agreed with the recommendations.

The results of the needs analysis were used to design the foundational mathematics course and redesign introductory statistics courses. The Foundational Mathematics course design team used backwards mapping to ensure that the problem-solving approach and real-life applications incorporated in the preparatory course provide students with the foundation they need for the redesigned statistics course. In particular, students developed problem-solving skills and an appreciation of the relevancy of mathematical and statistical concepts to their academic, personal, and professional lives.

Design of a New Statistics Pathway

The new preparatory course, Foundational Mathematics, was co-designed by a mathematics faculty member and a statistics faculty member; in addition, two adjunct faculty members assisted with the development of real-life application problems and answer keys. The course was designed to help students develop quantitative literacy skills by having them think about the entire process of solving a problem, including analyzing the question being asked, determining the appropriate method for solving the problem, and interpreting the results in light of the data provided and the context of the question.

The goals of incorporating the problem-solving model and real-life application problems were to enhance students' understanding of the relevancy of mathematical concepts to solving novel problems, thereby improving their metacognition and increasing the transferability of skills to new contexts. In the following section, both the problem-solving approach and real-life applications are described, and an example is provided to illustrate how the methods would be used in an online class discussion.

When doing math and statistics problems, it is often helpful to take a step back and think about the process you are using to solve them. To help with process, please use the following format when answering your discussion questions:

- **Question (or Problem) Being Solved:** Put the question that you picked from the list of weekly discussion questions in this section
- **Method Used to Solve:** Put the work you did to solve the problem, or, in the case of later statistics problems, what you used to calculate the answer.

  When reporting your work, please be sure to use the following standard mathematical practice:

  - Each step should show the complete expression or equation rather than a piece of it.
  - Each new step should follow logically from the previous step, following rules of algebra.
  - Each new step should be beneath the previous step.
  - The equal sign, =, should only connect equal numbers or expressions.

- **Results:** Write a complete answer to the question asked, including units, if appropriate

Figure 4-1. Three-step problem-solving model used for answering online discussion questions

Problem-Solving Approach

A three-step problem-solving model was developed and incorporated into the course to address the challenge of helping students develop critical thinking skills when solving mathematical and statistical problems. This instructional approach was intended to help students learn to use a systematic method to solving a mathematics or statistics problem from orientation through interpretation of results, and to understand when or if a step was missed. These goals were reinforced by having students use the approach in answering online discussion questions. *Figure 4-1* shows the three-step problem-solving approach taught to students.

Real-Life Applications

UMUC designed the foundational mathematics course to implement a holistic pedagogical approach. By using real life applications of mathematical and statistical concepts, the problem sets demonstrate to students how mathematical and statistical concepts are relevant to their college, personal, and workplace experiences, thereby increasing the transferability of career-relevant skills. Premadasa and Bhatia's (2013) study of college algebra students demonstrated that students preferred problems with some level of "intrigue" or that they could relate to their own lives, over generic application problems, pointing to an approach that might be more engaging to students.

Problem scenarios using real data were created to align with majors that require introductory statistics (e.g., business, healthcare management, psychology) and with other real-life situations (e.g., purchasing a laptop, etc.). Datasets were derived from information that was available from a variety of online sources, such as government agencies[10]. For some problems, students were asked to make recommendations based on the results of their analyses. For example, the scenario in *Figure 4-2* asks students to identify new business markets by using demographic data and calculating growth percentages over time.

Your business is planning to open additional branches in the Mid-Atlantic region. This region often includes New York, New Jersey, Pennsylvania, Delaware, Maryland, Washington, D.C., Virginia, and West Virginia. You want to place stores in states where there has been population growth, to help ensure a steady supply of customers.

The population estimates for the 8 Mid-Atlantic states and District of Columbia are listed in the table: (source: http://factfinder.census.gov/faces/tableservices/isf/pages/productview.xhtml?pid=PEP_2015_PEPANNRES&src=pt)

a) What is the percentage change in population between 2010 and 2015 for West Virginia? Round your answer to the nearest whole percent. Based on this answer, would you recommend opening a store in West Virginia?
b) What is the percentage change in population between 2010 and 2015 for Maryland? Round your answer to the nearest whole percent. Based on this answer, you would recommend opening a store in Maryland?

State	Population Estimate (as of July 1)	
	2010	2015
New York	19,402,920	19,795,791
New Jersey	8,803,881	8,958,013
Pennsylvania	12,712,014	12,802,503
Delaware	899,791	945,934
Maryland	5,788,409	6,006,401
Washington, D.C.	605,126	672,228
Virginia	8,025,787	8,382,993

The percentage change in population between 2010 and 2015 is defined as:

$$\frac{population\ in\ 2015 - population\ in\ 2010}{population\ in\ 2010} * 100\%$$

Figure 4-2. Real-life application problem scenario sample

After calculating the answer, students are then asked to decide whether or not to open a new store. Answers may vary, even when the calculated percentages are the same, which helps to highlight how decisions made with data often reflect individual student perspectives on the data and their analysis. For instance, one student may recommend opening a store given a 1% population change, while another student would only make that recommendation when there is at least a 5% population change. Providing a scenario students may encounter in a professional setting may enhance transferability of problem-solving skills applied in a specific context to different

[10] E.g., https://factfinder.census.gov, https://www.cdc.gov, and https://www.bjs.gov) and non-governmental organizations (such as https://ourworldindata.org and http://stat.wto.org

situations. Since students are required to post their approach to the problem in an online forum, all students are able to see the approach their peers took to similar questions and to learn from seeing other students' thought processes.

Problem Being Solved:

What is the percentage change in population between 2010 and 2015 for Maryland? Round your answer to the nearest whole percent. Based on this answer, would you recommend opening a store in Maryland?

Method Used to Solve:

Formula: $\frac{population\ in\ 2015 - population\ in\ 2010}{population\ in\ 2010} * 100\%$

Steps: $= \frac{6{,}006{,}401 - 5{,}788{,}409}{5{,}788{,}409} * 100\%$

6,006,401 - 5,788,409 = 217,992

217,992 / 5,788,409 = 0.03766

0.03766 * 100 = 3.766

Round answer to nearest whole percent: 4%

Results: There was a 4% increase in population in Maryland from 2010 to 2015.

Yes, I would open a store in Maryland based on the growth in population between 2010 and 2015.

Figure 4-3. Example student answer for a real-life application problem

Online Classroom Discussion Example Using a Scenario

Each week, a set of scenarios with real life applications is provided. The students each select one problem to answer and post their response in the online discussion forum according to the problem-solving format. The following solution is based on an actual student answer to the example provided in *Figure 4-2*.

Note that in the solution, the student used the recommended problem-solving approach to format their response. Furthermore, while there is a specific formula to use to solve for the percentage change in population, there are potentially multiple ways the final answer could be obtained. In this example, the student used three steps to solve the formula to obtain the solution. *Figure 4-4* shows actual feedback provided by a faculty member in response to an answer to the type of question displayed in *Figure 4-3*.

In addition to letting the student know that they did a nice job explaining the answer, the instructor's feedback reinforced how this type of information could be used in a real-life situation. In the case of an incorrect answer, feedback would provide guidance regarding where the error may have occurred, as well as resources to consult as needed.

> "You also did a nice job explaining your result. In real life, businesses make these types of decisions. There is no right or wrong answer about whether to open a store, with this growth margin; rather, the potential business developer decides what he/she considers to be an acceptable level of growth to make it worthwhile to open a new store."

Figure 4-4. Faculty feedback for real life application scenario problem

Online discussions using real-life application problems help students master the material through both observation and individual experience. In addition to working on their own scenarios, students can learn (and benefit) from seeing classmates' thought processes and answers to similar types of questions. Since each student has a different scenario, every answer will be unique, which helps to prevent simple copying and pasting of another student's answer.

Conclusion

UMUC used a comprehensive and integrated course design approach to address the prerequisite skills needed to be successful in introductory statistics, in particular through enhancing students' problem-solving skills and understanding of the use of statistics in everyday contexts. An important aspect of the process was the needs analysis to determine our particular student and institutional needs. The findings from the needs analysis led us to incorporate a specific problem-solving approach and real-life application problems in our preparatory statistics course, to help students develop and enhance quantitative reasoning that is more reflective of the 21st century knowledge and skills needed to succeed in college and in the workplace. Institutions considering implementing a new approach to teaching quantitative concepts may find that completing a needs analysis with relevant stakeholders is helpful in identifying and addressing the specific needs of their students in their respective programs.

References

Charles A. Dana Center at the University of Texas at Austin. (2015). *DMCP call to action: A call to action to expand access to statistics*. Retrieved from https://dcmathpathways.org/sites/default/files/resources/2017-05/Call%20to%20Action%20to%20Expand%20Access%20to%20Statistics.pdf

GAISE College Report ASA Revision Committee. (2016). *Guidelines for assessment and instruction in statistics education college report 2016*. Retrieved from: http://www.amstat.org/asa/files/pdfs/GAISE/GaiseCollege_Full.pdf

Morgan, D., Hall, S., & Shapiro, N. (2019). Counting on our future: First in the World (FITW) Maryland Mathematics Reform Initiative (MMRI). In R. Hartzler & R. Blair (Eds.) *Emerging issues in mathematics pathways*, pp. 77–86. Austin, TX: Charles A. Dana Center at the University of Texas at Austin.

Ngo, F., & Kwon, W. W. (2015). Using multiple measures to make math placement decisions: Implications for access and success in community colleges. *Research In Higher Education*, *56*(5). doi: 10.1007/s11162-014-9352-9

Premadasa, K., & Bhatia, K. (2013). Real life applications in mathematics: What do students prefer? *International Journal For The Scholarship Of Teaching And Learning*, *7*(2), Retrieved from https://eric.ed.gov/?id=EJ1135176

University of Maryland University College. (2018). About our students & alumni. Retrieved from https://www.umuc.edu/about/about-our-students-and-alumni/index.cfm

About the Authors

Margo Coleman-Seiffert has been with the University of Maryland Global Campus since 2003, teaching undergraduate statistics and psychology, and graduate counseling courses in UMUC's Stateside and Europe divisions. A frequent contributor to curriculum design and redesign projects, she taught pilot courses using Carnegie Mellon's Open Learning Initiative statistics and psychology courseware and coordinated the effort to redesign the undergraduate introductory statistics and statistics pathways courses.

Beth Mulherrin joined University of Maryland Global Campus in 1999. She partners with colleagues across the university on a variety of student success initiatives, including new student onboarding, developmental education, a required introductory research skills course for undergraduates, and large-scale curriculum redesign projects. She teaches grant and proposal writing and research skills at UMUC.

Author Note: The authors would like to thank the following UMUC faculty members for their work on the course: Dr. Kate Bauer (professor of mathematics) for co-developing the course, and Dr. Li-jen Lee and Mr. Frank Klein for their assistance in developing course materials. We would also like to thank Dr. John Beyers, the Program Chair for Mathematics and Statistics, for his support throughout the process of developing the course.

Chapter 5

HOWARD COMMUNITY COLLEGE'S PATHWAY TO STATISTICS

Carol Howald[11]

Howard Community College

Abstract

Over a three-year period, Howard Community College researched, developed, and evaluated a developmental mathematics course to prepare students placed at the elementary algebra level for a college-level introductory statistics course or mathematical literacy course, shortening their path to a college-level mathematics course by one semester. The work involved evaluating the developmental mathematics needs for students entering programs of study that require a statistics course or mathematical literacy course for the general studies mathematics requirement (rather than an algebra-based course), as well as considering other appropriate support structures such as a learning strategy course, tutoring, and early alert systems. Key assessment points in the process included assessing (1) the current developmental mathematics curriculum's alignment to support such a pathway, (2) the effectiveness of placement decisions, (3) the success rate of students in the pre-statistics developmental course, and (4) students' success in completing a college-level mathematics course within one year. Overall, there is evidence to suggest the project has shortened the pathway to college-level mathematics for a substantial number of students. The ABC rate for this course (61%) exceeds the ABC rate for the previous prerequisite for the college-level courses (55%) over the past 5 years. Of the students who completed the pre-statistics course, 61% have gone on to complete the college-level math course. For students initially placed two or more levels below college-level statistics who are in non-algebra-based programs, the pre-statistics pathway provides a more successful route to completing their college-level mathematics.

---

[11] Corresponding author: chowald@howardcc.edu; Mathematics Division, Howard Community College, 10901 Little Patuxent Parkway, Columbia, MD 21044

Often, developmental mathematics acts as a gatekeeper to progress for community college students (Bailey, Jeong, & Cho, 2010). Without obtaining college-level mathematics course credit, many students drop out without earning a degree or certificate. Given that approximately 71% of Maryland's community college students are placed in developmental math courses (Martin, Shapiro, & Marshall, 2017), the community college system has an important responsibility to carefully consider the range of students being served and the need for equitable access to the mathematics necessary to support their career goals. In addition to the analysis of MMRI-FITW project-defined variables and outcomes, Howard Community College used the impetus of the project to examine diverse institutional data as a lens to explore student progress toward completing college-level mathematics. Designing a supporting framework for student success involves understanding the variety of needs of a wide range of students.

Over a three-year period, Howard Community College researched, developed, and evaluated a developmental mathematics course to prepare students who placed into the elementary algebra level for a college-level introductory statistics course (MATH-138) or mathematical literacy course (MATH-132). (Appendix B contains a table with relevant course numbers and titles.) This developmental mathematics course would shorten their path to a college-level mathematics course by one semester. The course design process included evaluating the developmental mathematics needs for students entering a program of study that requires a statistics course or mathematical literacy course—rather than college algebra—as its general studies mathematics requirement. To support student success, Howard Community College also considered other appropriate support structures such as a learning strategies course (FYEX-100), tutoring, and early alert systems. To implement the new math pathway, Howard Community College's Mathematics Division worked with departments across campus to develop and implement the necessary placement and advising processes.

Building inclusive excellence was at the heart of the process. The college goals included uncovering inequities in student access and success, identifying effective educational practices, and building such practices for sustained institutional change. Instead of all students entering the traditional algebra-based sequence of developmental courses leading to a college algebra course, Howard Community College worked to design and implement a pathway to statistics more closely aligned with students' educational and career goals. *Figure 5-1* shows the courses in the traditional (algebra-based) and statistics pathways, and the content modules covered by each course.

Course Creation

Maryland's Statewide Mathematics Group (SMG) is composed of mathematics faculty representatives from many of the institutions of higher education in the state, including two- and four-year institutions. A review of the definition of a general education mathematics course was an important aspect of the initial work of the MMRI and the SMG leading to the course creation at Howard Community College. Code of Maryland Regulations (COMAR) require that all general education courses must be accepted in transfer by a receiving institution. The committee helps ensure that the transfer of general education credits is seamless across the state. The committee's work includes establishing a core definition for general education mathematics, expected student outcomes, and recommended core course components. It provides a setting to share syllabi and ensure that general education courses accepted for transfer will meet similar basic standards, outcomes, and goals, but without dictating standard curriculum for any course. The definition for the college level mathematics course drives the definition for the supporting developmental mathematics course(s).

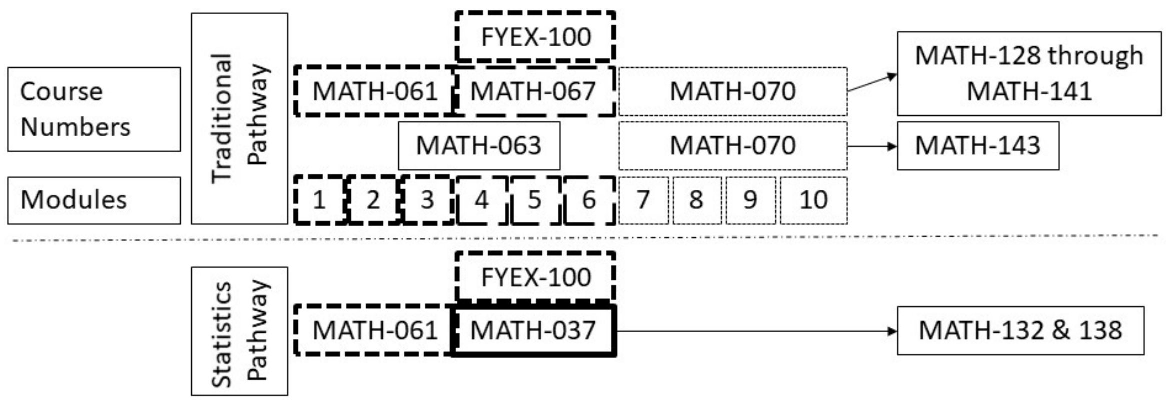


Figure 5-1. Mathematics pathways at Howard Community College

Initially, a general education mathematics course was defined as a course in mathematics at or above the level of college algebra. This definition assumed a traditional pathway where all students would learn the same algebra skills and concepts, regardless of the mathematical skills identified for their fields of study. This regulation prevented community colleges from considering and implementing recommendations from organizations that encourage instruction that focuses on the essential and meaningful mathematics necessary for a particular field. For example, the Statistics Committee of the American Mathematical Association of Two-Year Colleges (AMATYC) recognizes and supports the prerequisites identified by prominent statistics faculty and researchers in statistics education working in conjunction with the Dana Center. Many statistics faculty and researchers recognize that there are many topics in beginning and intermediate algebra that are not necessary for success in an introductory college statistics course.

The initial step in identifying prerequisite skills that students at the elementary algebra level need for success in Basic Statistics (MATH-138) was a review of the current objectives in the statistics course and the objectives of its traditional prerequisites, Elementary Algebra (MATH-67) and Intermediate Algebra (MATH-70). A committee of faculty individually rated which objectives were necessary prerequisites for our statistics course, discussed any differences in perspective, and resolved them through discussion and comparison to recommendations from bodies such as the Dana Center and AMATYC. Based on the list of objectives, it seemed reasonable to create a course that would halve the length of many students' coursework to prepare for Basic Statistics. The division dean planned and convened a meeting with the Advising Office, the Registrar, the Testing Center, the Records and Registration office, Student Support programs, the Financial Aid office, the Disability Services office, the Admissions office, and IT to engage central stakeholders in the process, ensuring all aspects of our students' campus experience were considered as the division moved forward.

Table 5-1. *Success Rates in Basic Statistics (MATH-138), Fall 2015, by Placement Level*

Basic Statistics (MATH-138)	**ABC Total (%)**	**ABCD Total (%)**	**FW Total (%)**
All students (*n* = 540)	301 (56%)	364 (67%)	176 (33%)
Students originally placed below MATH-067 (*n* = 65)	34 (52%)	40 (62%)	25 (38%)
Students originally placed in MATH-067 (*n* = 111)	62 (56%)	68 (61%)	43 (39%)
Students originally placed in MATH-070 (*n* = 77)	50 (65%)	59 (77%)	18 (23%)
Students originally placed as college-ready, at MATH-143 or below (*n* = 131)	78 (60%)	93 (71%)	38 (29%)
Students originally placed as college-ready, at MATH-145 or above (*n* = 21)	15 (71%)	18 (86%)	3 (14%)
Students with no placement values but cleared from dev. math (*n* = 135)	71 (53%)	86 (64%)	49 (36%)

Population

In addition to looking at the content necessary for the course, it was also important to consider the population to be served by this pathway and the barriers typically encountered in the traditional model. The Howard Community College Mathematics Division examined whether the type of placement in Basic Statistics (MATH-138) had a relationship with success in the course. They identified the level of mathematics that students initially placed into and final grades for students in all sections of Basic Statistics during Fall 2015. An analysis of the data looked for patterns across different placement levels (Table 5-1).

During Fall 2015, 540 students finished Basic Statistics with an A, B, C, D, F, or W. ABCD passing rates reflect course completion for general education requirements. Certain programs require an A, B or C for successful completion of Basic Statistics. Both F and W are unsuccessful outcomes for the course. The students who persisted to the college-level course after beginning in a course below the level of Elementary Algebra (MATH-067) had difficulty successfully completing Basic Statistics, given their success rate of just over 50%. Those students who originally placed into Intermediate Algebra (MATH-070) or into college-level mathematics using the ACCUPLACER placement exam were more successful in the statistics course than any other groups of students, according to their original placement level.

The group of students who originally placed into Elementary Algebra (MATH-067) or

Intermediate Algebra (MATH-070) are of particular interest for the development of the new developmental math course, Mathematical Foundations (MATH-037). Students who originally placed into and completed Intermediate Algebra (MATH-070) had a 77% completion rate in Basic Statistics (MATH-138), meeting preestablished division goals. Students who originally placed into Elementary Algebra (MATH-067) and had to complete both Elementary and Intermediate Algebra had a lower completion rate for Basic Statistics: 61%. Examination of institutional historical data revealed that, of the students who took Elementary Algebra, less than 60% were successful in moving onto Intermediate Algebra.

Students who placed directly into Basic Statistics (MATH-138) without a placement exam value have not fared as well those who use Howard Community College's placement exam (Table 5-2). This group contains students who were exempt from placement testing based on unrecorded SAT scores, transfer of credit from other institutions, or by taking honors Algebra II in high school. An important result of this investigation was an identification of and response to the need to track and understand placement and advising decisions more accurately.

Of the 135 students with no placement exam value, 41 transferred into college-level mathematics credit from another institution. On average, students who transferred a course at the level of Precalculus (MATH-143) or below performed weaker than those who transferred a course above precalculus. Ninety-four students were placed in Basic Statistics (MATH-138) with no record for the determination of the placement. We know anecdotally that some of these were placed based on SAT scores of 550 or more. With the lowering of the SAT threshold to 500 for placement into Basic Statistics (MATH-138), there is a chance that this method for placement will contribute to lower success rates for students placed directly into Basic Statistics (MATH-138) in the future.

Table 5-2. *Success Rates in Basic Statistics (MATH-138), Fall 2015, for Students Without a Placement Exam Value*

Basic Statistics (MATH-138)	**ABC Total (%)**	**ABCD Total (%)**	**FW Total (%)**
Students with no placement values but cleared from dev. math (n = 135)	71 (53%)	86 (64%)	49 (36%)
Students with transfer math credit MATH-143 or below (n = 29)	13 (45%)	15 (52%)	14 (48%)
Students with transfer math credit above MATH-143 (n = 12)	10 (83.3%)	11 (92%)	1 (8%)
Students with no transferred math credit (n = 94)	48 (51%)	60 (64%)	34 (36%)

Many institutions creating pathway courses to statistics recommend considering students' reading placement scores (e.g., Tennessee Board of Regents, 2016). Many of our students in developmental mathematics are also placed in a developmental reading course. With much of the course work in statistics conveyed in contextually bound problem settings, the need to have students reading at a college level is increasingly important. Although scaffolding the development of these reading and interpretation skills was incorporated in the pre-statistics course design, thereby complementing their work in a developmental reading course, it was also valuable to assess the relationship between reading placement and college-level mathematics course success for all students (see Table 5-3). While a D is a passing grade in Basic Statistics (MATH-138), a C or better is required in our developmental courses to move to the college-level course.

English courses below the level of ENGL-121, College Composition, are developmental reading courses. ENGL-08X courses are for students designated as needing ESL (English as a second language) services; ENGL-09X are for students who did not place into ESL courses. Students placed into ESL developmental reading courses performed better than the students placed in the equivalent non-ESL course, though the small number of students considered here should be noted. Of the students who did not place into ESL classes, those placed in College Composition (ENGL-121) have the highest success rates. Those with no placement values but cleared from developmental reading have the lowest success rates, reaffirming the need to track and understand placement and advising decisions more accurately. Based on these results, a consideration of reading level for placement is particularly valuable for our native English speakers. Based on recommendations from the Dana Center, we added a co-requisite learning strategies course for students enrolling in our developmental pre-statistics course. This decision was supported by campus studies by our English faculty indicating a correlation between success in the learning strategies course and success in developmental reading and writing courses.

Table 5-3. *Success Rates in Basic Statistics (MATH-138), Fall 2015, by Reading Placement*

Basic Statistics (MATH-138)	ABC Total (%)	ABCD Total (%)	FW Total (%)
All students (*n* = 540)	301 (56%)	364 (67.4%)	176 (32.6 %)
Students originally placed in ESL developmental (ENGL-083 or ENGL-086) (*n* = 35)	20 (57%)	24 (68.6%)	11 (31%)
Students originally placed in non-ESL developmental (ENGL-093 or ENGL-096) (*n* = 66)	30 (45%)	39 (59.1%)	27 (41%)
Students originally placed in ENGL-121 (*n* = 282)	163 (58%)	196 (69.5%)	86 (30%)
Students without placement values, cleared from dev. English (*n* = 157)	71 (45.2%)	86 (54.8%)	50 (32%)

Design of Howard Community College Pre-Statistics Curriculum

With state-wide objectives in place and an understanding of the needed pre- and co-requisites, the mathematics division began development of the new mathematical foundations course. Since many developmental courses are taught by adjunct faculty, Howard Community College intentionally involved an experienced adjunct familiar with our developmental mathematics program to assist in the course development. She brought the perspective of an adjunct without experience teaching the college-level statistics course and played the important role of judging the level and kind of instructor resources that would be helpful to our adjunct faculty. The inclusion of an adjunct faculty on the development team proved to be a valuable decision for a number of reasons, including increasing faculty buy-in. Her contributions to reviewing and improving the quality of the materials used were highlighted, ensuring that adjuncts teaching the course were confident that they could share their feedback as the course was implemented. The committee met weekly to review the ongoing work and provide feedback on the developing lessons. The committee used the first unit of the course to establish the basic structure of the guided student notes we would provide and the type of in-class work that would be woven into the remaining three units. Most lessons incorporate a classroom activity in which students are asked to begin a task using previously learned material that then becomes the basis for a classroom discussion that introduces new concepts and strategies. The new material is summarized by asking students to provide definitions or descriptions, which encourages their use of mathematical and statistical language.

In addition to class activities, the material regularly incorporates small group activities, think-pair-share activities, and on-your-own activities which encourage students to problem-solve both individually and collaboratively and to practice communicating with each other about the concepts in the course. These types of tasks allow the instructor to consult with small groups and individuals and provide specific feedback, as well as to assess individuals' progress in the class. Although the instructor's notes that parallel the students' guided notes include examples for all the objectives of the course, instructors know they must be prepared to provide additional examples as needed, depending on the mastery demonstrated during these types of activities.

The first day's lesson from Unit 1 demonstrates how these classroom strategies are woven together to support learning the material presented. The first classroom activity is based on data from a classroom survey. In this activity, students record their height in inches and their hand span in centimeters on the survey. The instructor sets up a Cartesian coordinate system on the board with the appropriate labels and asks students to quickly plot their data on the board. Students are expected to have an understanding of plotting points, but this serves as a quick review and confirmation. As a class, students describe the relationship they see in the graph. The instructor uses this discussion to introduce the terms positive association/correlation, negative association /correlation, and direction of association/

correlation. We extend the class activity using a think-pair-share activity to discuss whether the graph or the association would change if the heights had been recorded in centimeters. Some pairs respond to this by gathering a few data points using only centimeters to create a new graph; others address the question more abstractly. The sharing component allows students to see multiple strategies and helps students move towards a more generalized understanding of the role of the units in the graph.

The instructor's guided notes include possible solutions to each activity and provides information on common misconceptions, additional activities, and other resources available. There are also hints on how and when to incorporate different features of the graphing calculator and StatCrunch, the statistical software used in the course.

Each semester the course was taught, the teaching faculty kept notes and comments in their student and instructor guided notes packets to provide feedback for revisions. In addition, the instructional team met weekly during the first two semesters to address pacing and the depth of the material that students were experiencing. The ongoing feedback process resulted in some important revisions along the way, such as deciding the timing for each unit exam, the type of technology incorporated into each activity, and the number of practice problems needed in the written and online homework to support student success. As a result of a team recommendation, weekly checklists for students to support completion of online and written homework were created. At the end of each semester, a team meeting was held to review major revisions that were implemented and to flag components of the guided notes packets for future editing and revision.

At the end of the first academic year, the team made a major revision in the order of the units. For those less-prepared students who required a basic mathematics course before joining the pre-statistics course, we hoped to leverage the mathematics content the students had just experienced in Basic Algebra and Geometry (MATH-061). The team was pleased with the reordering of the topics given the improved performance on the more algebraic-focused units, which were moved to the first half of the semester.

Implementation

Student advising played an important role in the implementation of the new pathway to statistics. Based on historical records, the advising office estimated just under a quarter of Howard Community College students could be advised into this pathway based on their program needs. Initially, 6 sections of the course with 24 seats each were offered in Fall 2016. Advising staff were trained and provided information about the course and the advantages it would afford students. The mathematics division sent emails to students in appropriate programs who were enrolled in the traditional prerequisite courses, explaining the new course available. The elementary algebra instructors were informed as well, so they could answer any questions from students on the first day of class. In the end, the division ran 3 sections with only 45 students (total). The level of enrollment has increased in subsequent semesters, but the course has not reached the previously anticipated number of students (see Table 5-4 for other semester enrollments).

For Spring 2018, 51 students were identified as enrolled in elementary algebra but eligible to shorten their path to Statistics or Mathematical Literacy by enrolling in the pre-statistics course. Although the division reached out to them before the semester started by email, many students do not check their email regularly. Additionally, some students have set their schedules already for other classes and work and find it difficult to change their schedules. If Howard Community College is embracing a pathways model, students need to be aware of the choices and implications early.

As the mathematics division reports continued success for students in the course and as students share their personal success stories with their advisors, advisors are referring more students to the course coordinator for more information about the course. The mathematics faculty provide students with examples of how the courses differ in mathematical content and how it could still provide a good foundation for a wide number of programs. A number of students who had repeatedly failed the elementary or intermediate algebra courses were successful in the pre-statistics/statistics course sequence after working with their advisors to explore and devise a program of study that would allow them to move towards their career goals, despite their earlier struggles. With the buy-in from advisors increasing, the course is seeing increases in enrollment.

Table 5-4. *Mathematical Foundations (MATH-037) Enrollment Numbers*

Semester	No. of sections	Enrollment
Fall 2016	3	45
Spring 2017	4	51
Fall 2017	3	70
Spring 2018	3	54
Fall 2018	4	80

An overriding concern for advisors when working with students in programs eligible for the pre-statistics course is the loss of flexibility for students changing majors. Students who take Mathematical Foundations (MATH-037) are not eligible to continue to College Algebra (MATH-141) or Pre-Calculus 1 (MATH-143). Although an occasional student may decide to change programs and need to change pathways, there is ample evidence that this occurs infrequently, although the historical pattern at Howard Community College is difficult to track due to the lack of data maintained in the student record system. In the City University of New York (CUNY) system, of first-time associate degree-seeking students who declared a major from Fall 2011 to Spring 2013, only 4% changed from a non-mathematics intensive major to a mathematics intensive major (Charles A. Dana Center, 2018). Based on this and similar studies, the Dana Center (2018) recommends that

1) The normative practice for the student enrollment process helps students make informed choices from a small set of guided pathways and that their mathematics pathway should be based on that selection; and

2) Mathematics departments create viable alternative options to meet the needs of the small percentage of students who change from one mathematics pathway to another.

The benefit of shortening the college pathway for the vast majority of students identified with the appropriate major is huge in terms of cost, time to completion, and motivation to stay enrolled in college, particularly for students with interest in non-STEM fields who are placed in developmental courses. Howard Community College makes a concerted effort to have students complete their programs before transferring because this positively correlates with the completion of a four-year degree (Adams, 2013). Shortening students' path to college mathematics completion is a vital link in the chain.

Student Achievement Results

Each semester students' success rates were tracked to identify final grades and withdrawal rates for students with different initial placement levels. The results were broken out by placement level to help analyze the impact of the new pathway on student success. Students could be placed into Mathematical Foundations (MATH-037) through one of the following methods: (1) direct placement using ACCUPLACER; (2) by successfully completing one of the elementary algebra courses (MATH-061, 063, or 067); or (3) by not successfully completing Intermediate Algebra (MATH-070). Table 5-5 shows the success rates for Mathematical Foundations over its first three semesters, while Table 5-6 provides a summary, both according to students' original placement levels. In Table 5-5, students' original placement levels have been collapsed into MATH-067 and below (two or levels below credit-level math), MATH-070 and above (one level below or at credit-level math), given the small numbers of students in some cells and the importance of the line between one and two (or more) developmental courses needed to reach credit-level math.

Note that the success rate as measured by ABC rates is lower in the spring and second fall than in the first semester the course was offered. Twenty-one out of the 121 students (17%) in the later semesters were repeating the course, and 12 of the 21 did not earn an A, B or C (the requirement to move on to a college-level mathematics course) the second time. Typically, the number of absences a student holds has a substantial impact on the likelihood of success in our developmental math program, and that was the case for this course, as well. Of these 12 students, 9 missed at least 4 weeks of class, with an average of 11 absences. Of the 9 students who passed on the second attempt, the average number of missed days was 2.6 days. An important goal throughout the course is to keep students engaged in the material and the classroom interactions to encourage attendance. During the first semester, the average number of days of classes missed was 10.4 for all students earning an F in the course and 3.4 for all other students. Students who repeated the course and improved their attendance were successful in the course. We need to continue to make efforts to keep all the students engaged in the course, despite the challenges that many students face while attending community college.

Table 5-5. *Success Rates in Mathematical Foundations, Fall 2016 Through Fall 2017, by Placement Level*

FALL 2016	**Mathematical Foundations (MATH-037)**	**ABC Total (%)**	**ABCD Total (%)**	**FW Total (%)**
	All students (*n* = 45)	27 (60%)	33 (73%)	12 (27%)
	Students originally placed in MATH-067 and below (*n* =42)	24 (57%)	30 (71%)	12 (29%)
	Students originally placed in MATH-070 and above (*n* =3)	3 (100%)	3 (100%)	0 (0%)
SPRING 2017	**Mathematical Foundations (MATH-037)**	**ABC Total (%)**	**ABCD Total (%)**	**FW Total (%)**
	All students (*n* = 51)	26 (51%)	30 (59%)	21 (41%)
	Students originally placed in MATH-067 and below (*n* = 49)	24 (49%)	28 (57%)	21 (43%)
	Students originally placed in MATH-070 and above (*n* =2)	2 (100%)	2 (100%)	0 (0%)
FALL 2017	**Mathematical Foundations (MATH-037)**	**ABC Total (%)**	**ABCD Total (%)**	**FW Total (%)**
	All students (*n* = 70)	39 (58%)	45 (64%)	25 (36%)
	Students originally placed in MATH-067 and below (*n* = 63)	35 (55%)	41 (65%)	22 (35%)
	Students originally placed in MATH-070 and above (*n* =7)	4 (57%)	4 (57%)	3 (43%)

The ABC rate for this course (61%; see Table 5-6) exceeds the ABC rate for Intermediate Algebra over the past 5 years for Fall and Spring semesters (55%). Not only is the pathway to a college-level math course shorter, but there is an increase in the number of those completing their developmental mathematics needs.

Of the students who successfully completed the developmental course, Mathematical Foundations, with an A, B or C since AY2016-17, 61% have completed the college-level statistics course, 20% have withdrawn from or failed the college-level statistics course, and 18% did not enroll in any college-level mathematics course. Of those who have yet to finish their college-level math, 20% were enrolled in the college-level class for the following semester. The mathematics division needs to continue to work with advising to encourage these students to maintain their enrollment in mathematics until their college-level course requirement is met.

Overall, there is evidence we have shortened the pathway to college-level mathematics for a substantial number of students. For those completing the statistics course using this pathway, 27% were originally placed in Basic Algebra and Geometry (MATH-061). These students would have had longest path to college-level mathematics, but they now have a significantly shorter route that advisors are growing more confident in recommending to students. For those completing the pre-statistics course, 63% were originally placed in Elementary Algebra (MATH-067), and thus have shortened their pathways by a semester. For students placed two or more levels below college-level statistics who are in non-algebra-based programs, the pre-statistics pathway provides a more successful route to completing college-level mathematics, with less attrition along the way.

Table 5-6. *Success Rates in Mathematical Foundations (MATH-037), Summarized for All Semesters, by Placement Level*

Mathematical Foundations (MATH-037)	**ABC Total (%)**	**DFW Total (%)**
All enrollments placed in developmental mathematics (*n* = 164)	92 (61%)	74 (45%)
Enrollments originally placed in MATH-060 (*n* = 12)	6 (50%)	6 (50%)
Enrollments originally placed in MATH-061 (*n* = 44)	25 (57%)	19 (43%)
Enrollments originally placed in MATH-067 (*n* = 98)	52 (53%)	46 (47%)
Enrollments originally placed in MATH-070 (*n* = 10)	8 (80%)	2 (20%)

In addition, the initial placement level of these students does not tell their full mathematical story. Of the 145 unique students who have taken the pathway course, 32% (*n* = 47) were unsuccessful (D/F/W) in at least one prior developmental mathematics course, and 17% (*n* = 24) have at least 2 Ds, Fs, or Ws in their prior developmental mathematics courses. The statistics-based developmental course provides an important alternative for those students who have not had success in the algebra based developmental courses.

Implications and Next Steps

Key assessment points in the process of developing and implementing the new mathematics pathway included assessing the current developmental mathematics curriculum's alignment to support such a pathway; assessing the effectiveness of placement decisions; assessing the success rate of students in the pre-statistics developmental course; and assessing students' success in completing a college-level mathematics course within one year.

Our challenges continue to be (1) advising students into the pathway for non-algebra-based programs, (2) encouraging students to remain enrolled in mathematics until their college-level mathematics is completed, and (3) maintaining attendance for struggling students. With an increase of enrollment from 45 in Fall 2016 to over 80 in Fall 2018, we are seeing greater interest in the course. Letters or emails about the course sent to all students registered in developmental mathematics courses who are pursuing one of the targeted majors provided additional information, but students would benefit more by enrolling in the course as a first option, as opposed to being advised to change mathematics courses after their schedule had been created. The new pathway is highlighted in the advising manual, and the campus-wide developmental education committee consistently reaches out to support programs across campus about the developmental course offerings, their roles, and the improved results for students following the recommended path.

Howard Community College's examination of a variety of institutional-based data points as a lens to explore student progress toward completing college-level mathematics will continue to pay off for their students, staff and faculty. The institution and the community it supports as a whole win as our students move quickly and confidently towards their educational and career goals.

References

Adams, C. (July 11, 2013). Earning Associate Degree Before Transferring to 4-Year College has Advantages. Retrieved from https://blogs.edweek.org/edweek/college_bound/2013/07/earning_associate_degree_before_transferring_to_4_year_college_has_advantage.html

AMATYC Statistics Committee (2018). Mathematics Prerequisites for Success in Introductory Statistics. Retrieved from http://www.amatyc.org/?page=StatsResources

Bailey, T., Jeong, D.W., & Cho, S. (2010). Student progression through developmental sequences in community colleges. *CCRC Brief, 45*, 1–6. Retrieved from https://ccrc.tc.columbia.edu/media/k2/attachments/student-progression-through-developmental-sequences-brief.pdf

Charles A. Dana Center at the University of Texas at Austin. (2014). *The new mathways project implementation guide*. Austin, Texas: The University of Texas at Austin.

Charles A. Dana Center at the University of Texas at Austin. (2018). *Prevalence of students changing to STEM majors: Implications for math pathways*. Retrieved from https://dcmathpathways.org/resources/prevalence-students-changing-stem-majors-implications-mathematics-pathways

Huang, M. (2018). *2016-2017 impact report: Six years of results from the Carnegie Math Pathways*. San Francisco, CA: WestEd.

Martin, R., Shapiro, N., & Marshall, A. (2017, February). *Maryland math reform efforts: Purposeful mathematics pathways*. Presentation at the FITW annual meeting, Baltimore, MD.

Tennessee Board of Regents (2016). *Co-requisite remediation pilot study*. Retrieved from http://dcmathpathways.org/resources/mathematics-prerequisites-success-introductory-statistics

Williams, D.A, Berger, J.B. and McClendon, S.A (2005). Toward a Model of Inclusive Excellence and Change in Postsecondary Institutions. Retrieved from https://www.aacu.org/sites/default/files/files/mei/williams_et_al.pdf

About the Author

Dr. Carol Howald is currently an associate professor at Howard Community College in Columbia, Maryland, having previously taught in Missouri, New Mexico, and Arizona. She regularly teaches Statistics and strives to develop and incorporate ways to engage her students actively in class.

Chapter 6

PERFECTING THE RECIPE: MAKING THE RIGHT DECISION FOR A BLEND OF CONTENT IN A PRE-STATISTICS COURSE

Jessica Adams[12]

Harford Community College

John Bray[13]

Harford Community College

Abstract

Over a span of several years, Harford Community College realized that students who desired to complete our college-level statistics course were not as prepared as those students who intended to go through the conventional mathematics sequence commencing with college algebra or pre-calculus. A grooming Pre-Statistics course seemed essential. Our paper discusses the various steps in the evolution of this course, starting from scratch, taking into account the intent of the Maryland Mathematics Reform Initiative First in the World (MMRI-FITW) team, the active and enthusiastic participation of the student population, the course content, and many other elements. The culmination of all functions and activities became our current preparatory course, now in full implementation. This course is a developmental (pre-college level) course designed to prepare students for a statistics course offered at the college level. These pre-college level classes are known as transitional courses at Harford Community College. Inclusion of student success strategies contributed to the uniqueness of Harford's Pre-Statistics. Since its debut, the course has continually evolved. We hope that this paper will serve as a guide for others when beginning the development of a similar course.

---

[12] Corresponding author: JeAdams@Harford.edu

[13] Corresponding author: JBray@Harford.edu

Purpose

The purpose of this paper is to discuss the various steps in the evolution of a pre-statistics course, taking into account the intent of the First in the World (FITW) team, the involvement of the student population, the course content and many other elements. The culmination of all functions and activities is the current preparatory course, now in full implementation at Harford Community College. The course, Pre-Statistics, is a transitional course designed to prepare students for an introductory statistics course offered at the college level. Inclusion of student success strategies contributes to the uniqueness of Harford Community College's Pre-Statistics. We hope that this paper will serve as a guide for others when beginning the process of course development for a pre-statistics course.

Background

Introduction to Statistics at Harford Community College accommodates the greatest number of students who require a mathematics course for completion of an associate degree. There are two primary types of students enrolled: (1) students who need this course for their program or major, and (2) students who need a mathematics course to fulfill their graduation requirements. Based on the variability of student goals, desires, needs, and placement, we believed it was appropriate to create a "pre" course that would induce consistency in students' quantitative backgrounds that, in turn, would benefit both the students and the flow of the course.

The core of transitional courses we have at Harford has always been "algebra-focused," in that the algebraic concepts taught in pre-high school and high school are again presented to students. The intent was to ensure students were prepared for college-level algebra and follow-on courses such as pre-calculus and trigonometry. The concepts of probability, descriptive statistics, and sampling were not covered in the traditional transitional courses. Students who needed statistics would not be nearly as prepared as those who intended to navigate through algebra. Therefore, another reason for creating a pre-statistics course arose.

Introduction to Statistics at Harford Community College is a fast-moving course in which a substantial amount of material competes with a limited amount of time. A transitional course that would go into more detail with the basics would be well received and appreciated by students in this course. Pre-statistics would provide a baseline which Introduction to Statistics can build upon, adding much more substance to a strong mathematical foundation. Pre-Statistics would also be configured to allow more opportunity for students to engage in active learning strategies with activities that would make the concepts in Introduction to Statistics more easily digested and less foreign. Students' interest in learning would hopefully be piqued. With the appropriate level of flexibility built in, Pre-Statistics would allow more room for discovery.

Our reasons just stated, together with the MMRI-FITW grant mission, served as the argument for development of Pre-Statistics. Once this endeavor was approved, the challenge was then ours to construct and implement.

The Team

At Harford Community College, there is a diverse MMRI-FITW team. The project lead from the college was Chris Jones. The three full-time faculty members who developed the course were Jessica Adams, John Bray, and Chris Jones. The lead instructor of the course was (and still is) Jessica Adams, with adjunct instructors Michael Parker, Albert Ringgold, and Andrew McIntyre. The institutional research team that provided the data for the FITW grant included Valerie Swain, Patti Wilson and Junghyan Min, with Tim Schneider in advising. Pamela Runge from the Learning Center and Wendy Rapazzo from the STEM division assisted in the development of an Academic and Life Skills activity used in Pre-statistics. Elizabeth Holmes from the Humanities division developed the reading skills materials.

The Pathways

At Harford Community College, prior to the addition of the Pre-Statistics course, students had the potential of taking up to five transitional courses before they reached a college-level math course. This situation is potentially problematic because students who have to spend time in non-credit-bearing courses are less likely to complete the full course sequences. For example, according to Bailey and colleagues (2015), "just 30 percent of students referred to developmental math completed their sequence within three years, and only 16 percent completed a first college- level math course" (p. 121). In the statistics pathway, which contains Pre-Statistics, students are required to navigate fewer courses to complete their mathematics requirements. This situation, in turn, is anticipated to lower the attrition rate. This arrangement becomes a "selling point" for students who want to shorten their mathematics pathway.

We have several pathways of transitional courses that prepare students for college-level work. *Figure 6-1* depicts the current mathematics pathways (STEM Track and Liberal Arts Track) with the addition of the third, new Pre-Statistics and Statistics branch.

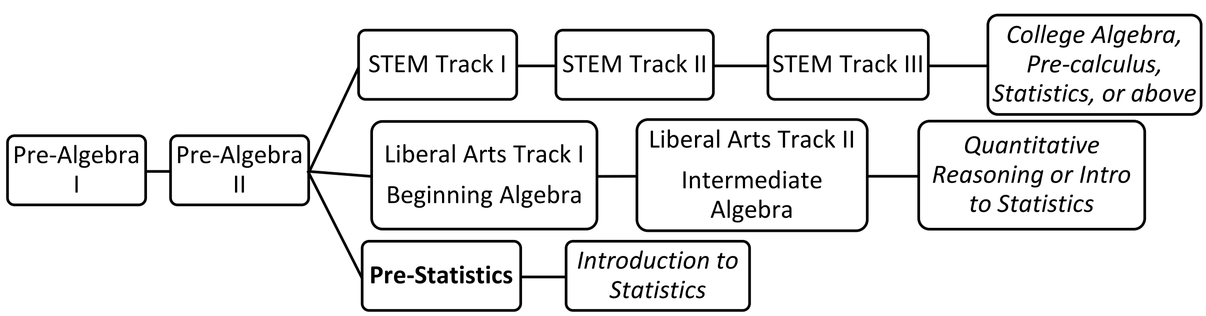


Figure 6-1. Three math pathways: Developmental and college-level mathematics course sequences

The Placement

Introducing the new course led to two major placement issues. Placement into Pre-Statistics was the first issue. The primary means of entering Pre-Statistics is the successful completion of one or both pre-algebra courses. The other means of entrance is placement directly into the course via a standardized exam. The most commonly used exam is the ACCUPLACER. We have determined that a floor score of 40 would be adequate to enter Pre-Statistics, at least until more data causes us to adjust the cut-score.

The other placement issue is more complicated: that of entering the college-level Introduction to Statistics course. *Figure 6-1* portrays several journeys that culminate in college-level mathematics courses. In addition to Pre-Statistics, two series of transitional courses lead to Introduction to Statistics. A Liberal Arts track (consisting of two transitional courses) and a STEM track (with three transitional courses) form the other paths. Based on their ACCUPLACER score, a student may begin anywhere in one of the three tracks. The track itself is determined by the student's goals at the time of enrollment but may change as he or she progresses through the college. Lastly, an ACCUPLACER score of 70 or higher was deemed appropriate for entry directly into Introduction to Statistics, bypassing all transitional courses. As is the case with Pre-Statistics, further analysis may alter this cut-off score as more data is obtained.

The Students

Harford Community College is composed of a diverse student body. First-time college students, adult learners, working professionals, dual-enrolled students, first-generation college students, active military, and career changers are a few of the populations served by Harford Community College. As an open-access institution, our college expects to have an assorted blend of students in every classroom. Since Pre-Statistics is a combined transitional course, there is a wide range of mathematical abilities among the students.

The Logistics and Timing

The class sizes for Pre-Statistics typically range from 18 to 32 students. Sections are offered during the day or evening, on weekends, and in online, hybrid (50% in-class and 50% online), and full face-to-face formats. Most classrooms are traditional, non-computer rooms, but instructors have access to computer labs as needed. The required materials are the Pearson MyMathLab online access with eBook. This eBook is a custom book which blends the content from *Algebra: A Combined Approach* by Elayn Martin-Gay, and *Informed Decisions Using Statistics* by Michael Sullivan. The Martin-Gay materials are also used in the beginning and intermediate developmental algebra courses at Harford Community College; the Sullivan materials are used in Introduction to Statistics. The decision was made to use a blend of the same materials to make an easier transition for students from one course to the next.

Discussion

Content

One aspect of Pre-Statistics that differentiated it from the other transitional courses at Harford Community College was the inclusion of a set of student success strategies as part of the course content. The student success strategies consist of study skills, time management, reading skills, note-taking skills, goal setting, growth mindset activities, and collaboration among students. Through our years of professional experience, we have found that many students who take a mathematics course are unable to properly study for a mathematics assessment. Students complete an Academic and Life Skills assignment that includes the following questions:

- What will you do before and during lecture?
- Where will you study?
- When will you study?
- How will you study?
- What are some healthy life skills that you can include in your day?

After these question are posed, the students then discuss in a think-pair-share the top five ways to study for a quiz or exam. Within this same activity, students also set goals for the course, their personal goals for the first exam, and goals for their overall coursework. After the first exam, students complete an exam reflection writing assignments in which they look back at the goals they had set for the first exam and the ways they had planned to study.

Another student success activity is the use of student journals. This activity allows students to work on self-reflection and writing skills without the expense of using class time. Students watch a short video in MyMathLab and compose a short journal entry in the course's learning management system. The journal activities include the following prompts:

- How is your attitude with respect to taking this course? If there is room for improvement, describe how you might improve your attitude.
- Is your goal for this course to successfully complete this course? If not, why not? Take a moment to write down your goals for this course.
- How organized are you in a math course? Have you ever not been able to find an important paper you needed? What steps will you take now to become more organized?
- Are you up-to-date on assigned topics in your math course? Include a discussion on times absent, times late, times when you are behind where you should be on assignments, etc. Discuss the steps you will take to improve in these areas.
- How do you currently complete a homework assignment? How might you do a better job if your goal is to fully understand the homework topic and successfully complete your course?
- What positive steps can you take to perform better on topics you have seen before in your math courses?
- List some steps you take before turning in a test that might help you improve your test score.
- List any common errors that you usually make during a quiz or test.

There is a direct and close relationship with the Learning Center on the campus at Harford Community College. Members of the Learning Center at Harford are invited to visit Pre-Statistics classes to present topics that the students would most benefit from, such as reducing stress, dealing with test anxiety, and managing time—and all of this complemented with general learning center information. The Learning Center also provides content included within the course's learning management system (Blackboard) for test preparation, test taking skills, and a post-test checklist. College campuses that have one or more learning centers available to students see increases in student success (Bailey et al., 2015).

Another component of the student success strategies is the inclusion of reading skills in the course. We have observed that many of our statistics students struggle with the reading portion of each problem and accurately decoding the question and data. This phenomenon might be related to the low levels of reading proficiency seen across the country on the NAEP exam. As of 2015, approximately two-thirds of 12th graders in the U.S. scored below "Proficient" on reading and 28% scored below "Basic." Furthermore, about three-quarters of 12th graders scored below "Proficient" in mathematics, and 38% scored below "Basic" (U.S. Department of Education, 2015). Various reading skill activities were developed for our pre-statistics course to help instructors aid students in improving their mathematics and statistics reading ability.

Lastly, the growth mindset activity is introduced at the beginning of the semester, which allows students to explore their capability to grow their intelligence. According to Mindset Works, "New research shows that the brain is more like a muscle—it changes and gets stronger when you use it" (Mindset Works, 2017). Students read the Mindset Works article "You Can Grow Your Intelligence" and answered the following questions independently, while considering their personal lives.

- Based on your own life, can you compare a challenge you have overcome to one that was presented in the article? If so, explain. If not, consider a challenge you are dealing with now, and discuss how you could apply ideas from the article to your current challenge. Specifically, what could you do over the next week to help you deal with the challenge?
- If the author's claim about the brain being like a muscle is accurate, what changes (if any) to your personal life would you recommend or consider? How might you approach reaching your goals regarding both this class and the statistics course you plan to enroll in? What changes would you recommend to Harford Community College?
- Think about the article "You Can Grow Your Intelligence" and your previous responses. Based on what you now know, what advice or encouragement would you give to your fellow students when they find themselves struggling as they learn new math skills and concepts?

Discussing the growth mindset at the beginning of the semester with the Pre-Statistics students, encourages them to improve their self-esteem and confidence in the course.

The challenge in establishing the mathematics content for Pre-Statistics involved "walking the elusive boundary" between two realms of quantitative skills. One side of this boundary provides students with enough breadth and depth of algebra concepts to serve them in future course work (other than statistics), without overwhelming them by presenting all of the concepts taught in transitional courses. The other side builds a basis for probability and statistics to pique the students' interest and improve success rates in Introduction to Statistics, while attempting to avoid too much redundancy from Pre-Statistics to Introduction to Statistics.

After several sessions of deliberation within the MMRI-FITW team, a "best guess" was made for the content. We all understood that this first iteration would be subject to additions, deletions, and shifts within the course. As anticipated, all of this happened. The initial cut for the course—owing to the ambition and enthusiasm of the Pre-Statistics team—included nearly all the algebra topics discussed in the transitional courses as they now exist. Putting this course in place for the first semester and overestimating the speed at which students would learn or master the subject matter, we ran out of time. The time allocated for the probability and statistics portions of the course (the last blocks of Pre-Statistics) was much more limited than what we had intended.

Evolution

Future iterations focused primarily on probability and statistics first, with the time remaining allocated to what we believed were the most important algebra topics to be included. Several concepts such as order of operations, simplifying expressions, solving linear inequalities, vertex form of quadratic equations, completing the square, and factoring presented in the transitional courses had to be sacrificed in favor of probability and statistics. Further details of the alterations of the course content from Fall 2016 to Fall 2018 are displayed in Appendix A. *Figures 6-2* and *6-3* show the transition of the initial construction of the course content to the most recent one.

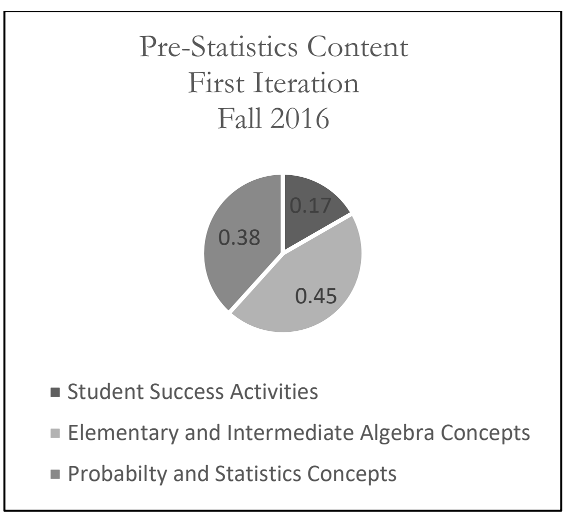


Figure 6-2. Pre-Statistics content, Fall 2016

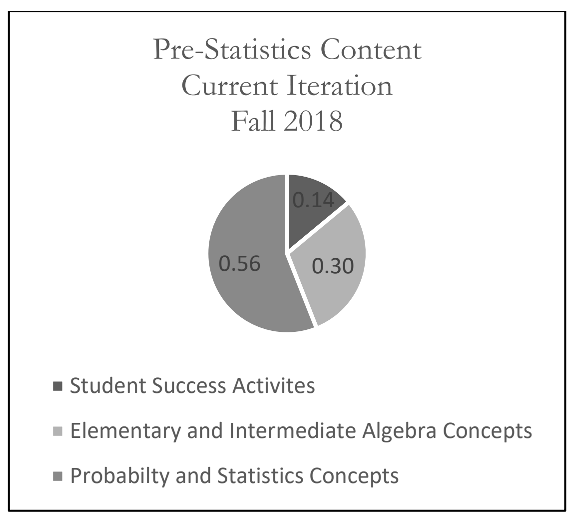


Figure 6-3. Pre-Statistics content, Fall 2018

The changes to the course built up over time after the close of each semester. After the instructor evaluations from Fall 2016 were reviewed, the general theme of recommendations for the course was "less algebra" and "more statistics" content moving forward. One of the other top themes from students was the appreciation of the student success skills that were built into the course. After each semester, the lead instructor would reflect on the pace of the course to determine if the proper time was allocated for each topic. Informal discussions with statistics instructors and Pre-Statistics students who went on to complete Introduction to Statistics supported the idea that more statistics content was needed and less algebra was required. Meetings with the MMRI-FITW team involved deliberation, editing, and polishing the course content, materials, and activities.

Conclusion

Perfecting the recipe for a developmental pre-statistics course is a challenging and on-going process. The various steps in the evolution of such a course, starting from scratch, involved taking into account the student population, course content, student placement, and many other elements. Now in full implementation at Harford Community College, Pre-Statistics is a transitional course designed to prepare students for college-level introductory statistics, with additional student success activities that resonate throughout all of their coursework. With this new course, students have a shorter pathway to college-level mathematics, and they are taught material more relevant to their college and career mathematics objectives.

We continue to consider various options for moving forward with Pre-Statistics at Harford Community College. One such consideration is the development of a co-requisite option for students who might not need a full semester of Pre-Statistics to be successful in Introduction to Statistics. With this idea, many more questions arise. How many credits would the combined course have? What would be the approach? What materials would be used? What placement scores would be used? Other options for the current Pre-Statistics model include the adoption of Open Access Resources to lower the cost of materials for students or adaptive online resources to provide personalized assignments tailored to students' individual strengths and weaknesses. These questions and other considerations discussed above reflect the reality of continual course developmental and re-design, which we found to be an important task for assuring appropriate and relevant content and instruction for our students.

References

Bailey, T. R., Jaggars, S. S., & Jenkins, D. (2015). *Redesigning America's community colleges: A clearer path to student success*. Cambridge, MA: Harvard University Press.

Mindset Works. (2017). You can grow your intelligence: New research shows the brain can be developed like a muscle. Retrieved August 15, 2018, from https://www.mindsetworks.com/websitemedia/youcangrowyourintelligence.pdf

U.S. Department of Education. Institute of Education Sciences, National Center for Education Statistics. (2015). NAEP data available for secondary analysis. Retrieved September 9, 2018, from https://nces.ed.gov/nationsreportcard/researchcenter/datatools.aspx

About the Authors

Jessica Adams has been an Assistant Professor of mathematics and statistics within the Science, Technology, Engineering, and Mathematics Division at Harford Community College, located in Bel Air, MD, since 2015. Jessica obtained her undergraduate degree in Mathematics from University of Delaware. She also earned her master's degrees from College of Notre Dame of Maryland in Education and from Johns Hopkins University in Applied and Computational Studies. In her free time, Jessica enjoys running, mountain biking, kayaking, and spending time with her three children.

John Bray is a full-time instructor of mathematics within the Science, Technology, Engineering, and Mathematics Division at Harford Community College (HCC) located in Bel Air, MD. Previously, John was the chair of the mathematics department at Broward Community College (Fort Lauderdale, FL) for eight years, an adjunct professor at several universities in Florida, and a member of the mathematics faculty at the United States Military Academy (West Point, NY) for three years. In addition to being faculty at HCC, he is a senior analyst for a defense contractor. His 22-year military career as an officer saw many and varied positions, including the commander of a logistics battalion and research officer within the Defense Logistics Agency.

Chapter 7

CO-REQUISITE STATISTICS COURSE FOR NON-STEM STUDENTS: DOES IT WORK?

Min A[14]

Coppin State University

Nicholas Eugene

Coppin State University

Abstract

This project investigates the effectiveness of a co-requisite, non-algebra-intensive developmental mathematics pathway at Coppin State University. The main goal of the article is to discuss whether the accelerated pathway has benefitted students long-term by enabling them to complete required math courses faster without sacrificing the mastery of solid mathematics foundation skills. Student performance in traditional and co-requisite groups was analyzed and compared to determine the effectiveness of the new co-requisite course.

Coppin State University adapted the co-requisite developmental mathematics model in Fall 2017, and 62% of the students enrolled in the new co-requisite statistics course passed with a grade of C or better. In comparison, 87% of students enrolled in a traditional basic statistics course demonstrated a similar level of achievement. Test mapping shows that co-requisite students acquired the same math skills as their peers in the traditional pathway. As expected, the average score of the co-requisite students' final exam was lower than the traditional basic statistics peers because students were less prepared academically and received instruction on broader learning objectives within a shorter period of time.

[14] Corresponding author: ma@coppin.edu; Department of Mathematics and Computer Science, Coppin State University, Baltimore, MD 21216

Poor performance among college students in developmental mathematics education in the United States is no secret. The tremendous efforts in redesigning developmental programs across several states have been observed to improve the success of student learning in developmental courses (Childers & Lu, 2017). Developmental mathematics courses have the highest failure and incompletion rates among all developmental subject areas (Bonham & Boylan, 2011). Bryk and Treisman (2010) asserted that if we truly want to make math the gateway rather than the gatekeeper to a college education, then developmental math is an obvious place to help students develop the knowledge, skills, and social connections needed for success beyond the math classroom. The high repeating and failure rates of developmental math courses and the high rate of students dropping out of college are related to many students exhausting their financial supports. The Mathematical Association of America stated that about 50% of students do not pass college algebra with a grade of C or above (Saxe & Braddy, 2015, p. 3). To address these problems, many campuses have sought to accelerate developmental mathematics courses (Saxon & Martirosyan, 2018). Co-requisite developmental mathematics pathways have been implemented at many two-year and four-year campuses in Maryland to help students master the necessary fundamental mathematics skills at a relatively faster pace.

Background and Course Description

There have been several developmental math course redesigns in the past decade at Coppin State University. Most students have tried to complete the traditional Elementary and Intermediate Algebra course sequence in two semesters. However, this course sequence created a roadblock for some students. In Fall 2016, Coppin State University started to offer a statistics pathway, a single semester four-credit-hour course. The statistics pathway was developed for non-STEM students aiming to accelerate their path through mathematics, and the redesign was supported by the Maryland Mathematics Reform Initiative-First in The World project (MMRI-FITW).

In Fall 2017, Coppin State University stopped offering the standalone developmental courses (Elementary and Intermediate Algebra) and implemented a co-requisite developmental mathematics program. The co-requisite program offers students the opportunity to complete the accelerated pipeline pathway courses in only one semester. Two courses were designed to fulfill the academic requirements for students' future career paths based on their majors: Co-Requisite College Algebra, for students who need college-level algebra or above for their major requirements, and Co-Requisite Basic Statistics, for non-STEM students who are eligible to use Basic Statistics (rather than college-level algebra) as the college-level mathematics course to fulfill graduation requirements. This project focuses on our evaluation of Co-Requisite Basic Statistics.

The course materials for Co-Requisite Basic Statistics were designed by following the *Mathematics Prerequisites for Success in Introductory Statistics from the Dana Center* (Peck, Gould, & Utts, n.d.). The basic structure of the course follows a "Boot Camp" structure (Dana Center Mathematics Pathways, 2017), which covers the developmental mathematics content in the first five weeks of class and the college-level content for the remainder of the course. After the fifth week, students take a post-test (exit exam), which covers the mathematics prerequisite content. Students who score 70% or higher on the post-test continue in Co-Requisite Basic Statistics for the next 10 weeks. Students who score below 70% spend the remaining 10 weeks studying the prerequisite content and retake the post-test at the end of the semester. Those who score 70% or higher at the end of the semester are eligible to take Basic Statistics the following semester (at no additional cost), and those who score below 70% are eligible to take Co-Requisite Basic Statistics the following semester (at no additional cost). (See Appendix D for a flow chart to illustrate potential paths and outcomes for students.)

Method

Students enrolled in Co-Requisite Basic Statistics took a pre-test on the first day of the class to measure their basic concept readiness, and during the first five weeks of class they reviewed the necessary developmental mathematics topics to prepare them for the success in the basic statistics portion of the course. Only students in non-STEM areas of study who passed the post-test with a score of 70 or higher and remained in Co-Requisite Basic Statistics were included in this research project. Therefore, the "co-requisite group" consisted of non-STEM students who passed the post-test in the fifth week and remained in the co-requisite course. The "traditional students group" took Basic Statistics after previously having passed two developmental math courses (Elementary and Intermediate Algebra). We compared the performance of students in both groups on three different measures: overall success rates, final exam grades, and correct responses on difficult versus easy exam questions.

First, the official final grades of 617 non-STEM students who enrolled in either the traditional or the co-requisite Basic Statistics courses from Fall 2010 to Spring 2018 were collected and analyzed. We compared the success rates for both groups to see if there was a significant difference between the groups of students. In addition, because students in the traditional and co-requisite courses were given the same final exam, we analyzed the final exam scores of students enrolled in each course in Spring 2018 to test the hypothesis that the co-requisite students, on average, earned a lower grade on the common final exam than students in traditional courses. We conducted *t*-tests to determine if there was a statistically significant difference between group average scores. To further measure student learning outcomes, we performed item analyses of each individual question in the common final exam. Using the test mapping technique, we identified the fundamental mathematics skills achievements of the two groups. Results of our analyses are presented below.

Results

Course Success Rates

We compared the official final grades of the Basic Statistics course from 617 traditional pathway and co-requisite statistics pathway students in non-STEM majors from Fall 2010 to Spring 2018. The entire co-requisite group in the study successfully passed the Basic Statistics course with a grade of C or higher; students who did not pass the post-test (exit exam) during the first five weeks of the course were excluded from the analysis. (See *Figure 7-1* for course final grades for traditional and co-requisite students.) On the other hand, 87% of students from the traditional pathway made a grade of C or higher. It suggests that the student-centered co-requisite program succeeded in speeding up mathematics pathway completion within only one semester, without lowering the quality of instruction. Obviously, this intensive learning effort paid off.

Standards in the co-requisite statistics course were not lowered; the course remained rigorous. Although more co-requisite statistics students passed the course, fewer earned an A. Fourteen percent of co-requisite students earned an A, compared with 27% of traditional students. Ten percent of co-requisite students earned a B, compared with 33% of traditional students. The shorter time to cover the required content and faster learning pace may have contributed to the differences in achievement.

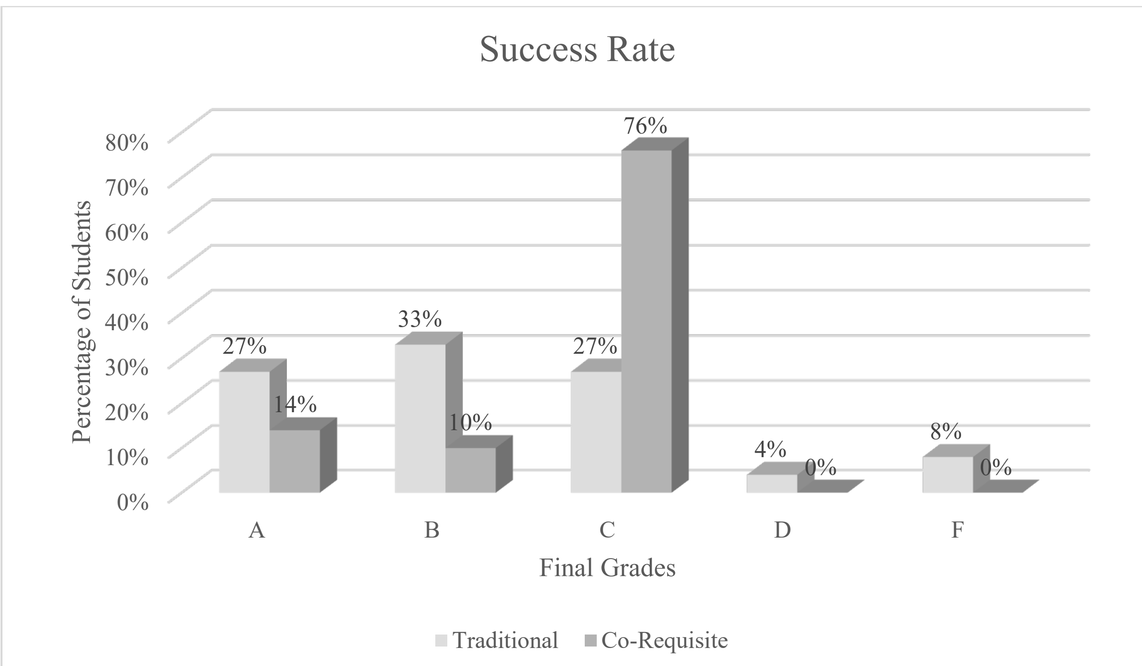


Figure 7-1. Comparison of final grades for traditional and co-requisite groups

Comparison of Final Exam Scores

A common departmental final exam was used to assess student achievement on learning outcomes in Basic Statistics in Spring 2018. The group of non-STEM-major students enrolled in the regular basic statistics course ($n = 45$) earned a mean score of 64%, with a range from 28% to 94%. The co-requisite group ($n = 30$) earned a mean score of 52%, with a range from 24% to 90%. The grade distributions of the two groups appear to have close ranges. Results from the t-test show that there exists a statistically significant difference between the mean final exam scores, $p < 0.01$. The results are not surprising because the co-requisite students started with fewer basic mathematics skills.

Item Analysis of Student Learning Outcomes

Spring 2018 students' performance on the common final exam was also analyzed by item type. The final exam consists of 50 multiple choice questions. We used test mapping (linking the intended learning objective to its corresponding item) to analyze each student's learning outcomes to compare the weaknesses and strengths of the two student groups. Item difficulty was determined by computing the overall rate of correct responses per item. The percentage of co-requisite students who correctly answered difficult questions was lower than the percentage of traditional students, whereas there was no significant difference in performance between the groups on the easy questions. The top five most achieved and most challenging student learning outcomes (SLOs) are displayed for the traditional group in Table 7-1 and for the co-requisite group in Table 7-2.

Table 7-1. *Learning Outcomes, Ranked by Easiest and Most Challenging: Traditional Group*

Rank	Most Achieved SLOs	%	Most Challenging SLOs	%
1	Find sample median	100%	Find the 91th percentile	36%
2	Find sample mean	98%	Confidence level of an interval	38%
3	Find simple probability (coins)	98%	Z score of an individual	38%
4	Find sample mode	96%	Find estimate a population mean	40%
5	Find sample range	93%	Application of normal distribution	40%

Table 7-2. *Learning Outcomes, Ranked by Easiest and Most Challenging: Co-Requisite Group*

Rank	Most Achieved SLOs	%	Most Challenging SLOs	%
1	Find sample mode	97%	Find the 91th percentile	13%
2	Find simple probability (coins)	97%	Counting outcomes (2 dice)	17%
3	Find sample mean	93%	Confidence level of an interval	20%
4	Find simple probability (marbles)	93%	Find odds in favor	20%
5	Find sample range	93%	Application of normal distribution	23%

Overall, both traditional and co-requisite student groups achieved the targeted learning outcomes of the Basic Statistics course. Both groups completed easy questions on the final exam, and success rates were all above 90% without significant differences between the groups. One advantage of the co-requisite program is that students review basic arithmetic skills in the developmental components and apply them to the statistics course within a short period of time, which makes the learning experience smoother and more continuous. On the other hand, students in the traditional pathway sometimes seemed to have a hard time recalling basic concepts, perhaps because they learned them one or two semesters prior to taking the final exam.

Co-requisite students struggled, especially as the difficulty levels of the questions on the final exam increased. The percentage of co-requisite students who answered difficult questions correctly was substantially lower than their peers in the traditional sections. Only 13% of co-requisite students correctly answered "Find the 91st percentile" while 36% of traditional students correctly answered the same question. Co-requisite students were weaker when completing the questions requiring multiple algebraic and arithmetic steps, while traditional students performed better on questions which required more critical thinking, high reading skills, and deep understanding. Understanding the underlying factors behind the differences between groups will require further investigation.

Conclusion

Co-Requisite Statistics opens a gateway for some students and helps speed up course work towards graduation. It helps students, especially first-years, to be more confident in their future college learning and saves private and public funds as well. Although student success rates in Co-Requisite Statistics were promising, there is still room to improve the newly implemented accelerated pathways to assist students to be more successful in future college life.

Institutions may offer more resources to help students transition from high school to college, to support them in building good study habits and mastering critical thinking and efficient time management skills. Improving the course curriculum consistently is another essential key to make the co-requisite program successful. In addition, interactive tools, such as MyMathLab, can deliver a welcoming teaching and learning technology platform. Sufficient and well-developed off-campus learning resources, such as workbooks and online learning textbook companion sites, should always be available. And last but not least, students who need to re-enroll in the co-requisite program should always be supported academically and personally to strengthen their learning techniques.

References

Bonham, B.S., & Boylan, H.R. (2011). Developmental mathematics: Challenges, promising practices, and recent initiatives. *Journal of Developmental Education*, *34*(3), 2–10.

Bryk, A. S., & Treisman, U. (2010). Make math a gateway, not a gatekeeper. *The Chronicle of Higher Education.* Retrieved from https://www.chronicle.com/article/Make-Math-a-Gateway-Not-a/65056

Childers, A. B., & Lu, L. (Fall, 2017). Computer based mastery learning in developmental mathematics classrooms. *Journal of Developmental Education*, *41*(1), 2–9.

Charles A. Dana Center at the University of Texas at Austin. (2017). *Co-requisite supports: Narrowing the gap between instruction and supports.* Retrieved from https://dcmathpathways.org/sites/default/files/resources/2018-02/Co-req%20supports.pdf

Kamii, M (1990). Opening the algebra gate: Removing obstacles to success in college preparatory mathematics courses. *The Journal of Negro Education*, *59*(3), 392–406.

Peck, R., Gould, R., & Utts, J. (n.d.). *Mathematics prerequisites for success in introductory statistics*. Retrieved from http://dcmathpathways.org/resources/mathematics-prerequisites-success-introductory-statistics

Saxe, K., & Braddy, L. (2015). *A common vision for undergraduate mathematics sciences programs in 2025* [Report from the Mathematical Association of America]. Retrieved from: https://www.maa.org/sites/default/files/pdf/CommonVisionFinal.pdf

About the Authors

Dr. Min A joined Coppin State University in 2008 after she earned her Ph.D. in Applied Mathematics from Southern Illinois University, Carbondale. Dr. A has served as the institution liaison of the FITW (First in the World) grant since 2015. She led the development of the new developmental mathematics pathway.

She has been awarded internal and external grants and has coordinated freshmen and developmental mathematics courses since fall 2009. Her main area of expertise lies in data analytics, application of partial differential equations and random walk modeling. She is a dedicated mathematics and statistics educator and researcher, focusing on offering solutions through data-driven approaches.

Nicholas Eugene is a Coppin grad, where he earned a degree in Mathematics, and holds a doctoral degree in Mathematics from Central Michigan University. In 2001, he rejoined Coppin State University in the department of Mathematics and Computer Science, where he currently serves as the Chair. In the past, he served as President of the Faculty Senate, Director of STEM Program and Freshmen Math Coordinator. He has been responsible for several redesigns of developmental mathematics, is active in professional development for Baltimore City Public School Teachers and leads undergraduate research in mathematics.

During his tenure at Coppin, he has received in excess of $2 million in grants. He is passionate about education and its possibilities. He is no stranger to education having spent 7 years as a teaching assistant at Central Michigan University and 18 years as a professor at Coppin State University. Today he encourages young people, especially women and minorities, to study the sciences.

In 2012, Dr. Eugene was inducted into Coppin's inaugural athletic Hall of Fame Class and again in 2016 as a member of the cross-country team that won three consecutive MEAC cross country championships. In his spare time, he likes to jog, play soccer, and play pool.

Chapter 8

WEDDED BLISS: LESSONS LEARNED FROM UNITING MATH PLACEMENT WITH MATH PATHWAYS

Charlita Woodruff-White[15]
Department of Mathematics, Morgan State University

Lisa D. Brown
Department of Biology, Morgan State University

Cheryl Rollins
Office of Institutional Research, Morgan State University

Jean-Pierre Liamba
Department of Mathematics, Morgan State University

Duvon Winborne
Center for Predictive Analytics, Morgan State University

Asamoah Nkwanta
Department of Mathematics, Morgan State University

Abstract

Placement into developmental courses impacts student retention and time-to-degree. For more than five years, over 65% of all first-time college students at Morgan State University have placed into developmental mathematics courses. Seeking to have an effective placement policy that supports math pathways for student success, Morgan's Department of Mathematics piloted the Assessment and Learning in Knowledge Spaces Placement, Preparation, and Learning program (ALEKS PPL) with 10 students who had completed Precalculus I. Results of the pilot were promising. Seven students who successfully completed the ALEKS PPL received credit for Precalculus II and enrolled directly into a calculus course; five of those seven students passed their calculus course. Lessons learned from this pilot program and next steps are discussed.

---

[15] Corresponding author: Charlita.Woodruff@morgan.edu; Department of Mathematics, Morgan State University, Baltimore, MD 21251

Morgan State University has a rich tradition of providing post-secondary educational opportunities to students who are often underserved in higher education. Typically, 60% of Morgan's incoming first-year students are Pell recipients and 20-25% are first-generation college students. Additionally, over the last five years, over 65% of all of Morgan's first-time college students have placed into developmental mathematics courses. Placement in developmental mathematics courses negatively impacts student retention (Rosin, 2012) and time-to-degree (Bailey, 2009; Long & Boatman, 2013). Currently, the second-year retention rate for Morgan's entering first-year students is 75%, while the six-year graduation rate is 39%. Improvement of these two rates is now the focus of a university-wide "50 by 25" campaign to increase six-year graduation rates to 50% by 2025. The components of this campaign include (1) enhanced advising and degree planning for students, (2) enhanced faculty development and course redesign, and (3) enhanced communication of support services for students available on campus and in the community. As part of this campaign, the university administrators and faculty inventoried successful campus practices to serve as potential models for expansion to other departments. One initiative included the redesign of general education courses with the goal of increasing student access to and participation in high-impact practices, which are widely tested teaching and learning practices that "have been shown to be beneficial for college students from many backgrounds, especially historically underserved students" (AAC&U, n.d.). Seven mathematics courses were redesigned to include a focus on creating common intellectual experiences, which is one type of high-impact practice (Alao et al., 2018). Another successful initiative has been the Foundations of Mathematics Program (FOM) administered by the Morgan State University School of Engineering. The FOM Program is a five-week online summer program that prepares students for the Morgan ACCUPLACER mathematics placement examination, using the Assessment and Learning in Knowledge Spaces (ALEKS) Placement, Preparation, and Learning (PPL) program for preparation for the exam. For the period of 2000 through 2015, out of a total of 366 participants, 13% of students who successfully completed the ALEKS PPL program placed into Calculus I, 23% placed into Precalculus, and 39% placed into Precalculus Part I. Only 25% of the participants placed into developmental mathematics. These results suggest that students who successfully complete ALEKS PPL would be on the path to graduating within four years.

"ALEKS is a mastery-based learning platform that identifies what […] students know, what they don't know, and what they are ready to learn" ("What is ALEKS?", n.d.), using adaptive release pedagogy—meaning, students are exposed to more advanced concepts only after they have mastered foundational concepts, which allows them to progress through the material at their own pace ("Overview of ALEKS," n.d.; "The ALEKS PPL Approach," n.d.). This process increases student confidence and momentum (Fisher, Brinthaupt, Gardner, & Raffo, 2015; Fisher, Gardner, Brinthaupt, & Raffo, 2014; Gardner, Fisher, & Raffo, 2011). ALEKS can be used for core course content instruction or as a supplemental instructional tool. ALEKS PPL is the placement assessment tool related to the ALEKS program and uses "a unique combination of adaptive assessment and personalized learning" ("ALEKS PPL: Pave the Path to Graduation with Placement, Preparation and Learning," n.d.) to ensure appropriate and accurate placement.

Incorporating ALEKS and ALEKS PPL into mathematics courses has previously proven to be successful at other universities, such as at the University of Illinois at Urbana-Champaign, where ALEKS was used for Calculus I placement and as a supplemental tool for students with additional instructional needs (Ahlgren & Harper, 2011; Harper & Ahlgren, 2013). Another such university is Kent State University, which began using ALEKS PPL in 2011. By using ALEKS PPL for placement, 80% of their students received a grade of C or better in Basic Algebra I, while only 10% received a grade of F or W. Enrollment improved, withdrawal rates decreased, and students performed better in their classes. ("Kent State University, OH," n.d.) Success stories such as these and Morgan's own FOM Program inspired the Morgan Department of Mathematics to pilot ALEKS PPL, with the thought that ALEKS PPL could replace ACCUPLACER for mathematics course placement, as well as lay the foundation for using ALEKS learning modules as part of course redesign for the developmental mathematics courses.

The work with ALEKS PPL at Morgan State University is germane to the purpose of the Maryland Mathematics Reform Initiative, funded in part by the First in the World grant (MMRI-FITW). Improving placement in mathematics courses clarifies the mathematics pathways for all students, regardless of their major. Better mathematics placement should improve student retention and reduce time-to-degree, especially for students in science, technology, engineering, and mathematics fields. Use of the ALEKS PPL program also will provide an impetus for course redesign that builds upon student success while maintaining mathematical integrity and rigor.

Methods

All first-semester students at Morgan State University (excluding transfer students and students admitted into the Center for Academic Success and Achievement program) are required to take a mathematics placement exam. For over 12 years, such math placement has been the ACCUPLACER assessment. The ACCUPLACER math component has been useful in providing the university information about a student's academic skills in mathematics, but it does not offer students any support in preparing for the placement exam. Furthermore, as described above, mathematics departments at several universities have achieved success after using ALEKS PPL. Therefore, the University is seeking to replace the ACCUPLACER with ALEKS PPL. ALEKS PPL uses adaptive questioning to quickly and accurately assess what mathematics content a student knows (and does not know). ALEKS PPL then instructs the student on the math topics she/he is ready to learn, based on that assessment. As the student completes the work, ALEKS PPL reassesses the student periodically to ensure that learned math topics are retained. The student must pass a predetermined percentage of the current topic assessment before advancing to the next topic. ALEKS PPL provides this individualized online instruction at any time. The university's goal was to officially utilize ALEKS PPL in lieu of ACCUPLACER, effective Summer 2018.

In August 2017, the Morgan State University ALEKS Committee was formed, composed of a small, select team of mathematics faculty dedicated to learning about and utilizing ALEKS PPL. The committee's objectives were to investigate strategies and discuss implementation proposals regarding the ALEKS PPL program that could ameliorate the university's retention and graduation rates, which aligned with Morgan's "50 by 25" Initiative. From December 26, 2017 to January 18, 2018 (the university's winter break), the ALEKS committee at Morgan State University initiated the ALEKS "Prep for Calculus" pilot program with a small group of students who passed Precalculus I in Fall 2017 with a grade of C or better. The covered topics and assessments in this pilot were aligned to the learning outcomes of Precalculus II. This pilot program included students in both STEM and non-STEM majors, ranging between freshman and sophomore status. The students were notified that their ALEKS access would be paid for by the mathematics department and they would receive credit for Precalculus II (MATH 114) and place into the next course, Calculus I (MATH 241), in Spring 2018 if they passed at least 75% of the final ALEKS assessment proctored at Morgan State.

Results

In order to obtain quantitative data on student performance and qualitative data on student perceptions of ALEKS, the ALEKS committee analyzed the success rates of the students who participated in the pilot program, distributed a questionnaire to investigate their experiences with the program, and authorized holding a focus group to collect more in-depth information about the students' experiences. The committee analyzed the data; results are presented in the following sections.

Success Rates in the Pilot Program

Initially 16 students volunteered to participate in this pilot placement program, of whom 13 students officially participated, and of whom 10 completed the program and took the final ALEKS assessment. Of those 10 students, 8 passed the final assessment (scoring at or above 75%) and received credit for Precalculus II, while 2 scored under 75% and placed into Precalculus II.

Students' Experiences in the Pilot Program

A web-based questionnaire was given to the students who participated in the pilot program. Based on the students' responses, the results of the pilot were overall successful. All nine students who completed the questionnaire revealed that the major incentive for the students participating in and completing this pilot program was to progress to Calculus I (MATH 241) without completing the traditional prerequisite course, Precalculus II (MATH 114). Of the nine students who participated in this survey, five students found ALEKS to be easily accessible. Six students in this survey spent an average of 45 minutes per day working on the modules. Eight students found the modules and homework in ALEKS to be helpful. Five students were very confident in taking the final assessment at Morgan State.

Overall, the students were satisfied with the ALEKS program and highly likely to recommend ALEKS to other students. Table 8-1 lists some of the positive experiences recorded from the students regarding using ALEKS as well as some aspects that students would change about using ALEKS at Morgan State University.

Students who did not finish the program primarily attributed their incompletion to not having access to a computer and/or internet over the university's winter break.

To investigate more deeply students' perceptions of the ALEKS system, we used a focus group interview as an additional data collection method. Morgan's Center for Predictive Analytics conducted the focus group and analyzed the students' perceptions and suggestions regarding the effectiveness of the ALEKS system and evaluated the potential adaptability and efficiency of future student use of ALEKS at Morgan. Five out of the 10 students who completed the pilot participated in this focus group, and all five were STEM majors. The students' positive perceptions of ALEKS closely matched the survey results. Overall, the students found that ALEKS provided many helpful tools for understanding the material, offered several examples within each module, and provided quality explanations for difficult problems. The main findings of this focus group study were determined by the ratings of the mean rank, model rank, and range. The summary of the major findings are displayed in Table 8-2.

A viewpoint that was not ranked but important to note is that some students thought there should have been better coordination with Calculus I and ALEKS, as Calculus I instructors should be aware of the content and teaching methods in ALEKS.

Table 8-1. Q*uestionnaire Results: Students' Reactions to the ALEKS Pilot Program*

Positive aspects of ALEKS PPL	**Recommended changes to ALEKS PPL**
Simplicity of accessing ALEKS	Have notifications appear when homework is due
System's ability to select topics specifically catered to their individual learning program	Assign ALEKS to every math course at Morgan State
Available step-by-step tutoring when they encountered a difficult problem or concept	

Table 8-2. *Focus Group Results: Students' Viewpoints on ALEKS*

Highest Ranked Viewpoints	**Lowest Ranked Viewpoints**
• ALEKS was easy to access and worked well. o ALEKS was easy to navigate and instructions were clear. o Information presented in ALEKS was readily understood.	• After ALEKS, they felt well prepared for their current mathematics course. o The content of ALEKS helped them with their current course. o ALEKS should be required for all incoming freshmen.

Limitations of ALEKS PPL

Overall, our research demonstrated that both ALEKS PPL and ALEKS, a web-based, adaptive-release learning system, can be used by students independently to learn and increase knowledge in basic mathematical concepts. However, as Morgan State University transitions to using ALEKS PPL as a tool for placing first-year students into appropriate math courses, it is important to note the challenges that may still impede accurate placement. Students will arrive at the university with various levels of preparation, dependent upon their engagement in supplementary ALEKS PPL modules prior to taking the final placement test. Thus there will be errors in placement that are not unique to ALEKS PPL but are, in part, a function of students' backgrounds, motivation, and independent efforts and, in part, inherent to any placement process. Some students who may actually be prepared for higher-level math courses may be placed in developmental courses, and some students who are truly unprepared may be placed in college-level math courses. Because of possible errors in placement, alternate pathways for fast-tracking students to college-level mathematics is critical, so that all students have the opportunity to reach and complete college-level mathematics courses as soon as possible and with the support they need.

Next Steps and Conclusion

Our pilot study demonstrates that when students are motivated and successfully complete ALEKS PPL modules, they can fill gaps in their knowledge and transition into higher-level mathematics courses. Previous research has shown that students who experience adaptive release modes of teaching in their courses view it favorably, particularly students who are underprepared (Fisher et al., 2014). The ALEKS PPL learning modules control the amount of information that is released, allowing students to master one concept before moving on to subsequent concepts. Additional research has shown that students who engage in online adaptive release activities become more self-directed learners and earn higher average semester grades than those who might not engage to the same degree (Fisher et al., 2015; Gardner et al, 2011). Thus, students guide their own learning, become more confident in their abilities, and are more inclined to persist to completion.

Despite the use of ALEKS PPL to enhance placement of students, more than 65% of first-year students at Morgan State University still place into developmental mathematics courses. At the end of Fall 2017, DFW rates for developmental mathematics courses were approximately 30%. The percentages are similar for precalculus courses. Precalculus has been a hurdle for incoming first-year students and is also a major roadblock to successful completion of the introductory courses for majors in both biology and chemistry (BIOL 105, Introductory Biology for Majors, and CHEM 105, Principles of General Chemistry I), particularly because Precalculus is a prerequisite for General Chemistry. An examination of data from 2006-2015 shows that students are 3.6 times more likely to pass General Chemistry (CHEM 105) if they pass Precalculus I (MATH 113). Data for Introductory Biology (BIOL 105) show similar results: Students are 5.4 times more likely to pass Introductory

Biology (BIOL 105) if they also pass Precalculus I (MATH 113). Thus, the need for alternate pathways to fast-track students from developmental mathematics courses to college-level mathematics is critical. Collaboration between these departments is ongoing to improve student pathways to success in STEM.

Based on comments made during the focus group which highlight the need for better alignment of classroom instruction with concepts taught by ALEKS, our subsequent pilot (conducted during Fall 2018) integrated the use of active learning strategies and ALEKS PPL with classroom instruction in three paired experimental and control course sections of Developmental Mathematics and three paired experimental and control course sections of Precalculus I. The focus was on horizontal alignment of course content, objectives, and goals with supplementary modules and assessment in ALEKS for the experimental course sections, compared to traditional instruction for the control course sections. Preliminary results indicate a decrease in DFW rates in the experimental precalculus courses. Analysis of the experimental developmental mathematics courses is on-going. In addition, we are also working to optimize integration of ALEKS into the classroom curriculum and supplemental instruction. We anticipate a reduction in DFW rates and possible subsequent placement of these students in higher-level mathematics courses. If successful, our long-term goal is to scale up the course redesign to include even more sections to help improve student success. This alternate pathway will contribute to a reduction in time to degree completion. This is particularly important for students in STEM majors, for whom advanced mathematics courses are prerequisites or co-requisites for science courses in their major, and being able to catapult to those courses will help accelerate students' progress through their programs. More broadly, the use of ALEKS PPL as a tool for placement and ALEKS as a supplement to classroom instruction will help create alternate pathways for student success in mathematics and will positively impact Morgan State University's retention and graduation rates.

References

Association of American Colleges & Universities (AAC&U). (n.d.). High-impact educational practices. Retrieved from https://www.aacu.org/leap/hips

Alao, S., Rollins, C., Brown, L.D., Wright, H.L., Seabrooks, Y., Thompson-Johnson, T., & Hardges-Scruggs, L. (2018). Increasing student access to high-impact practices: Inclusive excellence project findings. In *A vision for equity: Results from AAC&U's project committing to equity and inclusive excellent: Campus Based Strategies for Student Success* (pp. 37–40). Washington, DC: Association of American Colleges and Universities.

Ahlgren, A., & Harper, M. (2009). Assessment and placement through Calculus I at University of Illinois. *Notices of the AMS, 58*(10), 1460–1461.

Bailey, T. (2009). Challenge and opportunity: Rethinking the role and function of developmental education in community college. *New Directions for Community Colleges*, *145*, 11–30.

Fisher, L. S., Gardner, J. G., Brinthaupt, T. M., & Raffo, D. M. (2014). Conditional release of course materials: Assessing best practice recommendations. *Journal of Online Learning and Teaching*, *10*(2), 228–239.

Fisher, L., Brinthaupt, T.M., Gardner, J., & Raffo, D. (2015). The effects of conditional release of course materials on student performance. *Journal of Student Success and Retention, 2*(1), 1–14.

Gardner, J. G., Fisher, L. S., & Raffo, D. M. (2011). Best practices for using conditional release in online classes. *International Journal of Instructional Technology and Distance Learning, 8*(10), 3–16.

Harper, M., & Ahlgren, A. (2013). Detecting concepts crucial for success in mathematics courses from knowledge state-based placement data. Retrieved from https://arxiv.org/abs/1312.1127

Kent State University, OH: Placement Solution Improves Student Success. (n.d.). Retrieved from https://www.aleks.com/highered/math/case_studies

Long, B. T., & Boatman, A. (2013). The role of remedial and developmental courses in access and persistence. *The state of college access and completion: Improving college success for students from underrepresented groups*, *1*, 1–24.

Overview of ALEKS [webpage]. (n.d.). Retrieved from https://www.aleks.com/about_aleks/overview

Rosin, M. (2012, February). Passing when it counts: Math courses present barriers to student success in California community colleges (Issue Brief). Mountain View, CA: EdSource.

The ALEKS PPL approach [webpage]. (n.d.). Retrieved from https://www.aleks.com/highered/ppl/placement_approach

About the Authors

Charlita Woodruff-White is a Mathematics Lecturer at Morgan State University. She is the Co-Coordinator of the "Fundamentals of Mathematics" courses within the Department of Mathematics. She has been involved in several projects to better understand teaching methodologies pertaining to Mathematics and to improve educational outcomes and experiences for first-year students and students in fundamental courses. She is the Assistant Director of the Summer Academy of Mathematics and Science program (SAMS) at Morgan State University, a program that enriches academic enhancement and promotes interests in the STEM disciplines to high school students. In addition, she has been coordinating with the Department of Biology at Morgan State University to initiate a summer bridge program that would embolden critical thinking skills of first-year STEM students with the goal of improving university retention rates.

Lisa D. Brown, PhD is an Associate Chair and Associate Professor in the Department of Biology at Morgan State University. She has shifted from bench work to focus on strategies that promote undergraduate research training and the development of critical thinking skills in STEM-related disciplines. As the Coordinator of the Honors Program within the School of Computer, Mathematical and Natural Sciences, she has developed a series of Honors Interdisciplinary courses that focus on the development of critical thinking skills through writing exercises, analysis of scientific literature, and the development of either a research-based or literature-based thesis. Dr. Brown was awarded an NSF HBCU-UP grant to implement an academic program that promotes critical thinking activities, high-impact teaching practices and research experiences that will increase persistence (retention) of students in STEM following the freshmen year.

Cheryl Rollins, PhD has been the Director of Institutional Research at Morgan State University since 2006. Her research interest is predictors of student retention and graduation. She collaborates with colleagues across departments on this topic. Additionally, she serves on several statewide data advisory groups that have the purpose using data to support student success. In her spare time, Cheryl enjoys reading and cycling.

Jean-Pierre Liamba received his Ph.D. in Mathematics at the University of Wisconsin-Milwaukee in 2000 and is currently a Mathematics Lecturer at Morgan State University. He received the “Chairman’s Teaching Award” in Spring 2017 and the “Clara I. Adams Honors College Distinguished Faculty Award” in Spring 2018. He is the principle investigator of a mini-grant from the Morgan State University Lumina HBCU Student Success project: “Redesign Math Courses in ALEKS Project” in Fall 2018. He is an author of many books, such as “Calculus II: A Simplified Approach” and “Introductory Analysis II.” He serves on various university committees, such as chair of the ALEKS Committee, chair of the Senior Evaluations Committee, and co-coordinator of the Calculus sequence courses.

Duvon G. Winborne, PhD currently serves as the Chief Psychometrician at the Center for Predictive Analytics at Morgan State University. His higher education teaching experiences have primarily centered on graduate courses in statistics, research design, measurement, and computer programming. These academic experiences are augmented by management and consulting positions with government agencies, private corporations, and non-profit organizations. Dr. Winborne has an extensive publication record that includes over 50 refereed articles, book chapters and scholarly papers. Topics included in his research portfolio cover a broad spectrum, ranging from infant development to institutional research to statistical methods and psychometrics.

Asamoah Nkwanta is currently Chair and Professor of Mathematics at Morgan State University. He has many years of leadership and teaching experiences at the college and university levels. He has worked on numerous interdisciplinary projects that involve research topics on the theory of theatre from the performing arts, ribonucleic acid (RNA) from molecular biology, active learning techniques from mathematics education, and bioinformatic algorithms from computational mathematics. His academic research interests are algebraic and enumerative combinatorics, mathematical biology, mathematics education, and the history of mathematics.

Author Note: The authors express their gratitude to the faculty, staff, and administration at Morgan State University for their insightful contribution to this pilot: ALEKS Committee (Dr. Nadia Enurah, Dr. Syafrida Syafrida, Mr. Patrick Wenkanaab); Office of the Provost (Dr. Gloria Gibson, Dr. Solomon Alao, Dr. Yacob Astatke); Office of Enrollment Management and Student Success (Dr. Kara Turner, Dr. Tiffany Mfume, Dr. Brenda James, Ms. Rolicia Martin, Dr. Ernest Brevard, Jr.); School of Engineering (Mr. James Fletcher, Dr. Monica Poindexter); School of Computer, Mathematical, and Natural Science (Dean Hongtao Yu); Department of Biology (Dr. Cleo Hughes-Darden); Department of Chemistry (Dr. Angela Winstead); Mr. Sam Hussey of ALEKS

APPENDICES

APPENDIX A: UNIVERSITY OF MARYLAND, BALTIMORE COUNTY

Table A-1. *Course Numbers and Names Key*

Courses Fulfilling GEP Math Requirements		**Developmental Math Courses**	
Course Number	**Course Name**	**Course Number**	**Course Name**
STAT 121	Introduction to Statistics for the Social Sciences	MATH 099	Introductory Algebra
MATH 120	Introduction to Contemporary Mathematics	MATH 104	Quantitative Literacy
MATH 150	Precalculus Mathematics	MATH 106	Algebra and Elementary Functions
MATH 151	Calculus and Analytic Geometry I		
MATH 152	Calculus and Analytic Geometry II		
MATH 155	Applied Calculus		
MATH 215	Applied Finite Mathematics		
MATH 221	Introduction to Linear Algebra		
MATH 225	Introduction to Differential Equations		
MATH 251	Multivariable Calculus		

APPENDIX B: HOWARD COMMUNITY COLLEGE

Table B-1. *Course Numbers and Names Key*

Course Number	Course Name
MATH-061	Basic Algebra and Geometry
MATH-063	Introduction to Elementary Algebra
MATH-067	Elementary Algebra
MATH-070	Intermediate Algebra
MATH-037	Mathematical Foundations
*MATH-132	Topics in Mathematical Literacy
*MATH-138	Basic Statistics
*MATH-141	College Algebra
*MATH-143	Precalculus I
*MATH-145	Business Calculus
ENGL-083	Academic Intermediate Reading for ESL Students
ENGL-093	Directed Studies in Reading (non-ESL)
ENGL-086	Academic Advanced Reading for ESL Students
ENGL-096	Fundamentals of Academic Reading
FYEX-100	First Year Experience

*denotes course that fulfills graduation requirement

APPENDIX C: HARFORD COMMUNITY COLLEGE

Table C-1. *Pre-Statistics (Math-027) Content by Topic*

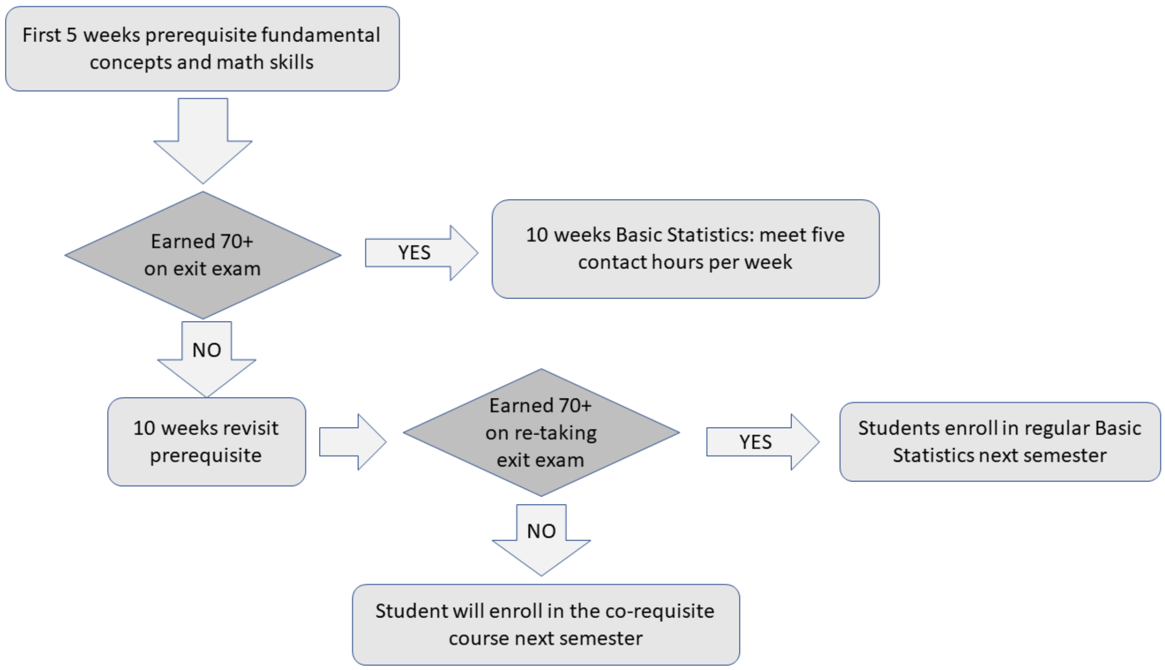
First Iteration (Fall 2016) Hours		Recent Iteration (Fall 2018) Hours
10.0	**Student Growth**	8.0
27.0	**Elementary and Intermediate Algebra Concepts**	18.0
1.0	Order of operations	--
1.0	Cartesian plane, plotting, and graphing	--
1.5	Slope calculations & interpretation; straight line formulation	1.5
1.5	Quantitative literacy and scenarios	1.0
1.5	Relationships in two variables; introduction to functions	--
1.0	Functional notation and meaning	--
2.0	Applications of linear equations	--
2.0	Applications of linear inequalities	--
1.0	Rules of exponents	1.0
0.0	Scientific notation	0.5
1.0	Exponential expression manipulation	0.5
1.5	Exponential functions and models; applications of exponents	2.0
1.0	Polynomial definition and classification	1.0
1.0	Polynomial operations	0.5
1.5	Polynomial addition, subtraction, and multiplication	2.0
1.0	Quadratic function and introduction	0.5
0.5	Standard form of quadratic functions	--
1.5	Vertices; vertex form of quadratic function	1.5
0.5	Graphing quadratic functions	1.0
0.5	Factoring	0.5
1.5	Solving quadratic equations with factoring	1.0
0.5	Solving quadratic equations with quadratic formula	0.5
1.5	Quadratic function applications	1.5
1.0	Radical function operations, evaluation, and graphing	1.5
23.0	**Probability and Statistics Concepts**	34.0
--	Linear regression; scatterplots	2.0
--	Correlation coefficient	2.0
1.5	Calculator functions; data inputting and storage functions	1.5
1.5	Basic descriptive statistics	1.5
1.0	Calculator one-variable statistics	1.0
--	Five-number summary and boxplots	2.0
1.5	Collection and types of data	1.5
1.5	Introduction to statistical methods	1.0
2.0	Sampling schemes; sampling hands-on activities	2.0
1.0	Types of data; organization and displays of qualitative data	1.5
1.0	Frequency districbution; relative frequency	1.5
1.5	Displays of quantitative data; histograms and relative frequent histograms	1.5
1.5	Measures of central tendency; mean, median, mode examples	1.5
0.5	Dispersion; standard deviation with formula and with calculator	1.0
1.5	Introduction to probability	1.5
1.5	Addition rule; complements; mutual exclusivity	1.5

First Iteration (Fall 2016)		Recent Iteration (Fall 2018)
1.5	Multiplication rule; independence; conditional probability	1.5
--	Tree diagrams and contingency tables	2.0
--	Hands-on exercises	2.0
--	Introduction to College Statistics (Math 216) at Harford CC	4.0

Hours	% of Course	**Summary**	Hours	% of Course
10	10/60 = 16.7%	Student Growth	8	8/60 = 13.3%
27	27/60 = 45.0%	Elementary and Intermediate Algebra Concepts	18	18/60 = 30.0%
23	23/60 = 38.3%	Probability and Statistics Concepts	34	34/60 = 56.7%

APPENDIX D: COPPIN STATE UNIVERSITY

Figure D-1. Potential paths for non-STEM students in Co-Requisite Statistics



APPENDIX E: GLOSSARY OF TERMS:

co-requisite support

Co-requisite supports provide "just-in-time" support for students enrolled in credit-level courses but who have been designated as underprepared for college-level coursework and require additional support to engage with the course content. The term is broad and may take many forms, depending on such features as time and nature of content delivery.

developmental courses

"Developmental" has replaced the term "remedial" and refers to courses that teach content below the college level.

gateway course

The "gateway course" is the first credit-bearing course following a developmental sequence; it provides college-level, transferable course credit.

pathway

A mathematics pathway is the mathematics course or sequence of courses required for a student's program of study. It may include developmental courses aligned with the gateway mathematics course, as well as the gateway course itself. Developmental courses that are not aligned with a gateway course are not part of a pathway. Credit-bearing courses beyond the gateway course may be part of the pathway, but our primary focus in this publication is on developmental and gateway courses in a pathway.

prerequisite (developmental) courses

Prerequisite developmental courses are designed for students who have been designated as underprepared for college-level coursework; these students are required to complete the prerequisite developmental courses before enrolling in college-level, credit-bearing courses.