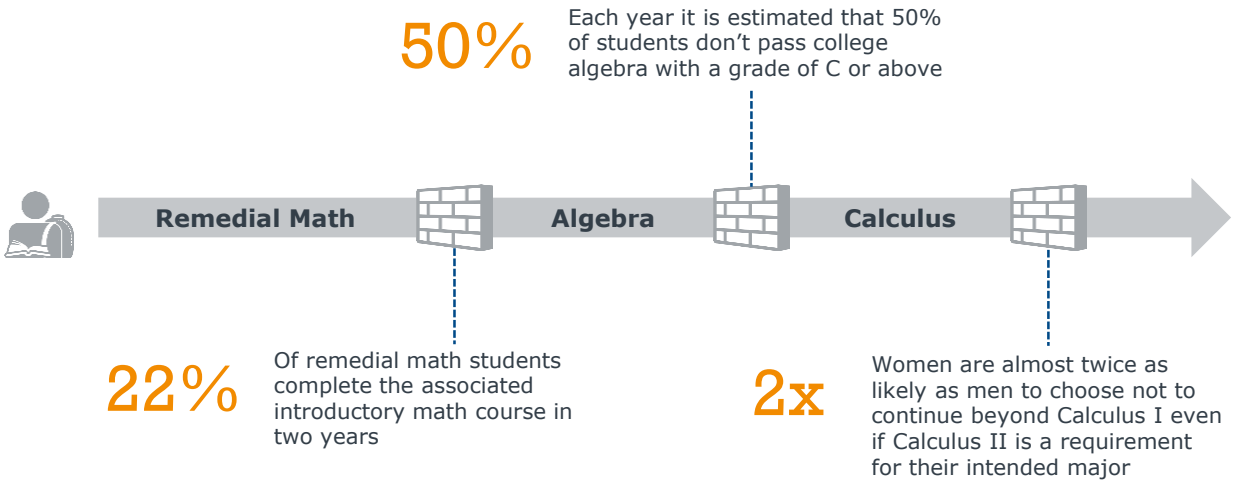
Redesign Curricular Pathways to Support Student Success

Gateway or Gatekeeper?

Traditional Math Pathways Contribute to Attrition and Student Equity Concerns

An often-cited student success concern is a lack of academic preparation, especially in math, among incoming first-year students. In 2015, 38% of twelfth grade students performed below basic math levels in their NAEP assessments. In order to address this concern, many colleges and universities offer remedial education. However, research indicates that only 22% of students[1] enrolled in math remediation complete the associated introductory course and only 17% of students[1] enrolled in any remedial education go on to graduate.

Remediation and Traditional Math Pathways Impede Student Progress



> "I remember in the math community, we dreamed up this idea of "math for all" — "algebra for all." What we've got now is "algebra forever" for these students…You're looking at someone going into interior design trying to factor trinomials. Policemen, firemen, EMTs … most people should not be focusing on that narrow piece of mathematics. They should be focusing on mathematics for use.
>
> *Uri Treisman, Founder and Executive Director, Charles A. Dana Center, University of Texas at Austin*

Moreover, underrepresented students comprise a disproportionately high share of developmental education enrollments. At four-year institutions 27% of Latinx students, 37% of black students, and 30% of Pell recipients are enrolled in remedial math (compared to 24% all students and 19% of white students).

Beyond just the use of academic remediation, traditional math curricula that overemphasizes the importance of the algebra to calculus pathway does not effectively support all students. Not only is college-level algebra a common academic barrier for most students but it does not give them the necessary foundation for the math course that aligns with their intended major. Students in the social sciences or humanities would benefit more from a course in statistics and quantitative reasoning instead of calculus.

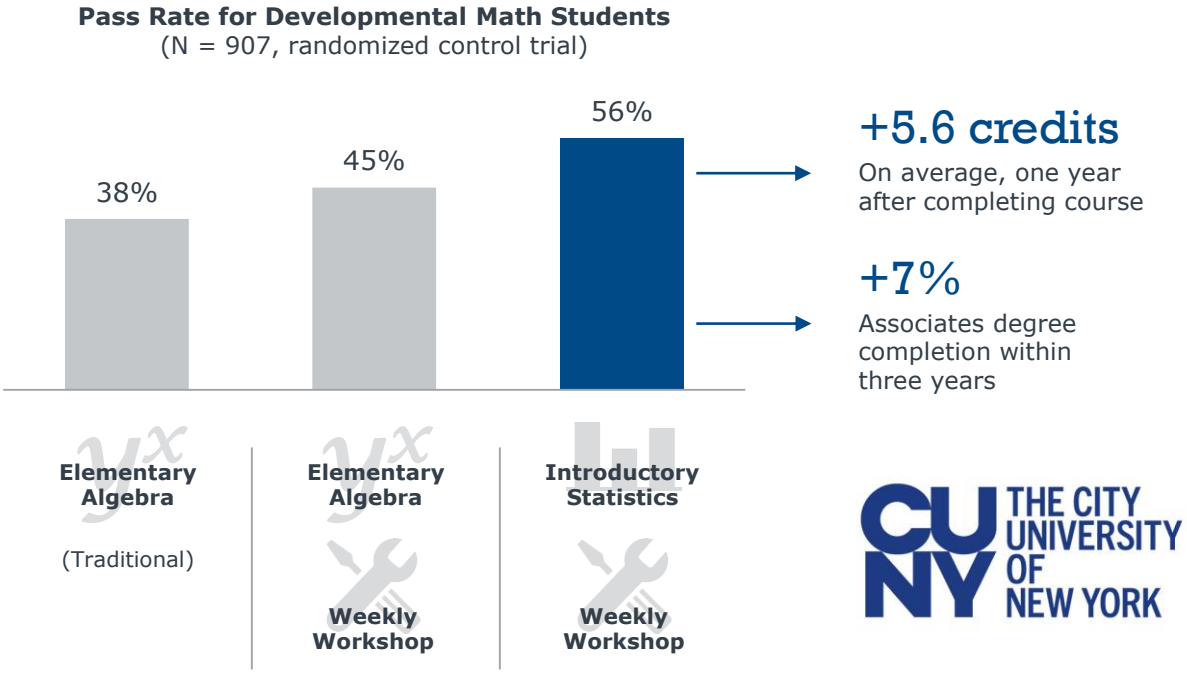
Source: Complete College America, "Corequisite Remediation: Spanning the Completion Divide"; Karen Saxe and Linda Braddy, "A Common Vision for Undergraduate Mathematical Sciences Programs in 2025", *Mathematics Association of America;* Complete College America, Data Dashboard; Elizabeth Zachry Rutschow and John Diamond, "Laying the Foundation: Early Findings from the New Mathways Project", *MDRC,* April 2015; The Nation's Report Card, 2015 Mathematics & Reading at Grade 12.

1) Includes students at both two and four year institutions.

Developmental Pathway Reform

Replacing Algebra with Statistics Dramatically Improves Outcomes

Corequisite education is seen as a mechanism to support academically underprepared students without creating a vicious cycle of required but not-for-credit developmental education courses. Under this model, students who have been assessed as not yet ready for introductory math courses receive extra help while they take a college-level course instead of taking a prerequisite, noncredit developmental course in mathematics, reading or writing. Research coming out of the CUNY system demonstrates that such a model improves completion rates in introductory algebra.



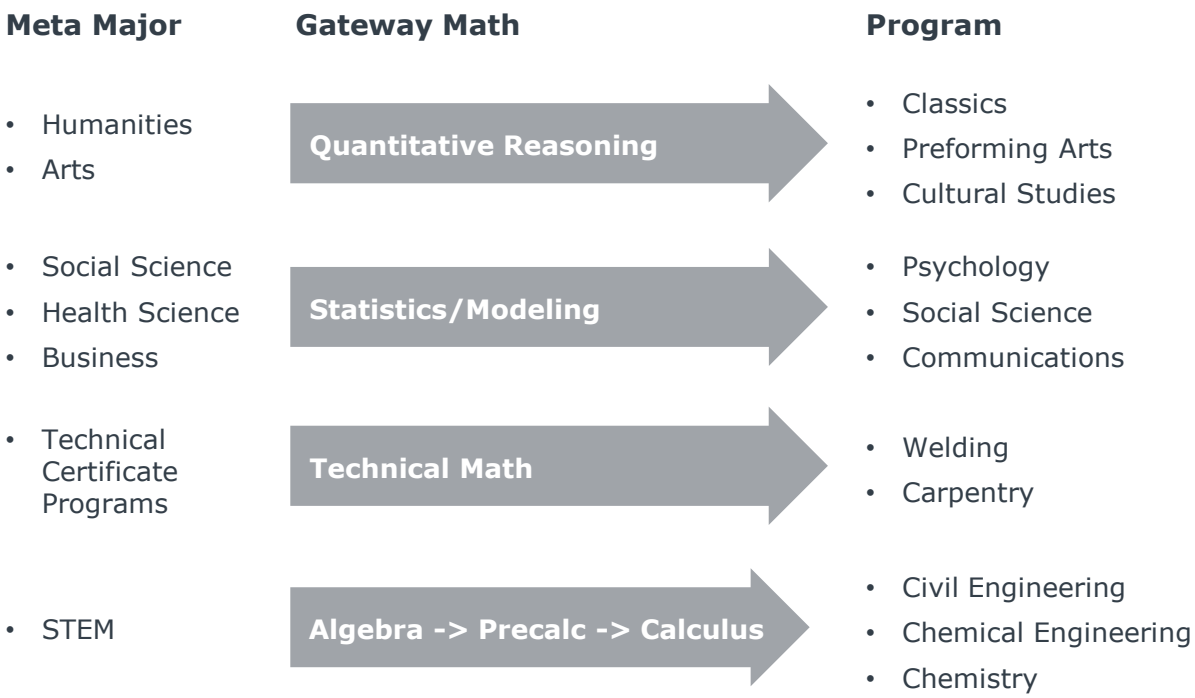
The study included a third option as well: introductory statistics. Researchers conducted a randomized control trial by placing 907 community college students into one of three courses: traditional remedial elementary algebra; the same course accompanied by a weekly workshop; or introductory college-level statistics with a weekly workshop. The two-hour weekly workshops were taught by undergraduate students and covered topics that students often found difficult in each course. Results indicate that students enrolled in courses with corequisite education passed their courses at higher rates – this was especially true for students in the introductory statistics course. Moreover, almost 50% more of the introductory statistics students graduated in comparison to students placed in traditional math remediation.

Source: Alexandra W. Logue, "The Extensive Evidence of Co-Requisite Remediation's Effectiveness" *Inside Higher Ed,* July 17, 2018; EAB interviews and analysis

Math Requirements Aligned to Majors

Most Students Won't Need Calculus, So Why Do We Make Them Take It?

The success of statistics students at CUNY demonstrates the importance of developing intentional institutional math pathways. Such course sequencing encourage students to complete introductory, college-level courses that aligns with their intended program of study. On most college campuses students are guided into College Algebra which is inappropriate for non-STEM students. A more student-aligned pathway would create different gateway math courses while guiding students into the appropriate course based on their academic and professional interests



For example, for most students hoping to major in the humanities and arts a quantitative reasoning[1] course is more useful given its broad applicability. Similarly, for most social science and business students' courses in statistics and modeling would help prepare students for their future coursework and careers. In fact, the traditional algebra to calculus pathway would only remain useful for students intending to major in STEM courses such as chemistry and engineering.

1) As defined by the Association of American Colleges & Universities, quantitative reasoning is the application of basic mathematics skills to the analysis and interpretation of real-world quantitative information in the context of a discipline or interdisciplinary problem to draw conclusions that are relevant to students in their daily life.

Source: Complete College America, Math Pathways; EAB interviews and analysis.

Major Aligned Pathways Boost Math Completion

Integrated Support for Underprepared Students Critical To Success

Many institutions have changed their academic pathways to accommodate the diverse interests and preparation of their student body. The Charles A. Dana Center at the University of Texas at Austin developed multiple pathways to track students into statistics, quantitative reasoning, or algebra based on their intended major. This model was first implemented in 2013 at nine colleges in Texas and initially included a developmental math prerequisite – the Center has since moved towards a corequisite model. An assessment of the pathways at four of the Texas colleges found that more students in the new pathway passed developmental math and enrolled and passed in college-level math.

Dana Center Mathematics Pathway[1]

Multiple Math Pathways Aligned with Major

Students enrolls in statistics, quantitative reasoning, or algebra depending on their major

Integrated Corequisite Support

Although initially a developmental math sequence, the Dana Center now recommends corequisite models

56% Of students passed developmental math (compared to 48% in traditional sequence)

25% Of students passed college-level math (compared to 17% in traditional sequence)

Carnegie Math Pathways[2]

Two Primary Pathways with Multiple Variations

- **Statway**: single-term accelerated or yearlong college-level statistics course with corequisite support
- **Quantway**: options include yearlong or single-term college-level quantitative reasoning course with corequisite support or a single-term college-level course without additional support

54% Of yearlong Statway students passed college-level math within one year (compared to 6% in traditional sequence)

63% Of all Quantway students passed developmental math within one semester (compared to 21% in traditional sequence)

Similar math pathways created by the Carnegie Foundation in 2011 also show promising results. The Carnegie pathways include two primary sequences. Statway, as the name suggests, includes single-term accelerated and yearlong statistics courses with integrated corequisite support. On the other hand, Quantway includes similar course variations for students taking a quantitative reasoning course. A study of 39 colleges that implemented these pathways found that a higher percentage of Statway students earned college-level math credit within one year than students in the traditional math sequence. Similarly, an analysis of 27 colleges that implemented the Quantway sequence found that more students in the new pathway passed developmental math than their peers in the traditional developmental math sequence.

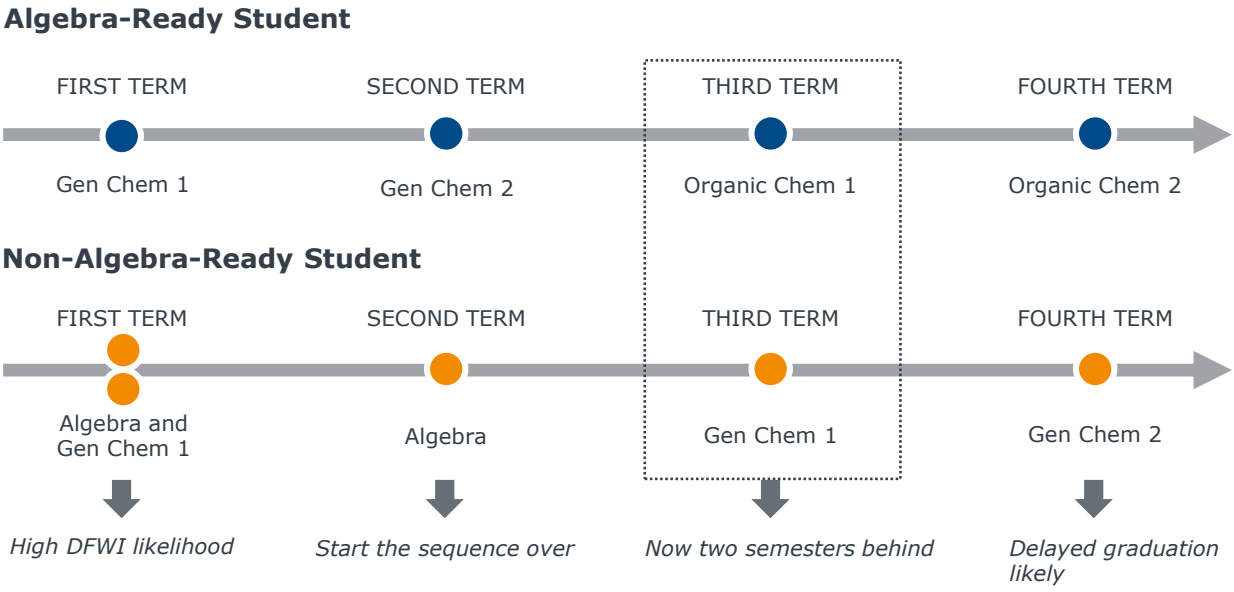
1) Developed by the Charles A. Dana Center at the University of Texas at Austin
2) Developed by the Carnegie Foundation for the Advancement of Teaching and now run by WestEd

Source: Elizabeth Ganga and Amy Mazzarielo, "Math Pathways Expanding Options for Success in College Math", *Education Commission of the States and Center for the Analysis of Postecondary Readiness,* Oct 2018.

Have We Built Equity Barriers into Our Curricula?

Front-Loading Math-Heavy Content Can Create Multi-Term Delays

Not only do current math pathways create barriers for student progression, major course sequences, especially in STEM, also create roadblocks for students. One illustrative example of this problem is in the chemistry curriculum. Given the level of algebra needed to be successful in introductory chemistry, non-algebra-ready students, who are more likely to be from underrepresented communities, are at a disadvantage compared to their more academically prepared peers.



Major Switch Patterns Point to Curricular Challenges

35%

Of students[1] who declared a STEM major changed their field of study within three years of enrollment (compared to 29% of non-STEM students)

36%

Of students who persisted in a STEM major took introductory college-level or lower math in their first year (compared to 63% who took calculus in their first year)

80%

Of underrepresented STEM first year students at EAB University[2] did not complete a STEM baccalaureate degree

These students must either enroll in algebra and introductory chemistry concurrently, a course combination that increases their likelihood of DFW, or they must postpone taking introductory chemistry until after completing the necessary algebra requirement. Both these options adds time to degree and discourages underrepresented students from pursuing the major.

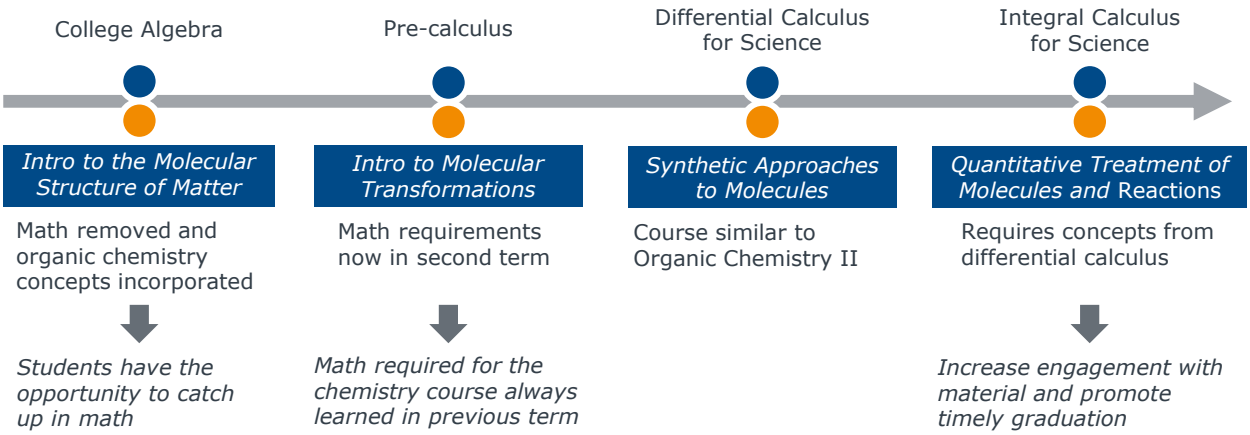
1) Undergraduates entering in 2011/12 academic year
2) Pseudonym

Source: Chen, Xianglei and Mathew Soldner. "STEM Attrition: College Students' Paths into and Out of STEM Fields." *U.S. Department of Education,* 2014; RPI News, Howard Hughes Medical Institute Awards $1.2 Million Grant to Rensselaer To Improve STEM Persistence., May 29, 2014; Beginning College Students Who Change Their Majors Within 3 Years of Enrollment, U.S. Department of Education, December 2017; EAB interviews and analysis

Delay Math but Boost Engagement and Equity

Faculty-Driven Curricular Redesign Experiment May Level the Field

To address this problem, a chemistry professor and former Provost at the University of Texas at San Antonio piloted a redesigned four course introductory chemistry pathway for 50 environmental science majors. The introductory chemistry course in the new sequence removed any concepts that required prior algebra knowledge from the curriculum and replaced it with more engaging aspects of organic chemistry. Content that required math was moved into the second course in the sequence which allowed underprepared students to take introductory chemistry and algebra concurrently.



A Pilot with Non-Majors (Hopefully) Leading to Major Path Change

UTSA The University of Texas at San Antonio™

- New pathway created by John Frederick, former provost and professor
- First cohort included 47 students, majority of which were environmental studies majors
- First course emphasizes elements of inclusive pedagogy including peer-led learning, instruction on working together in groups, multiple formats to learn the material, and open educational resources

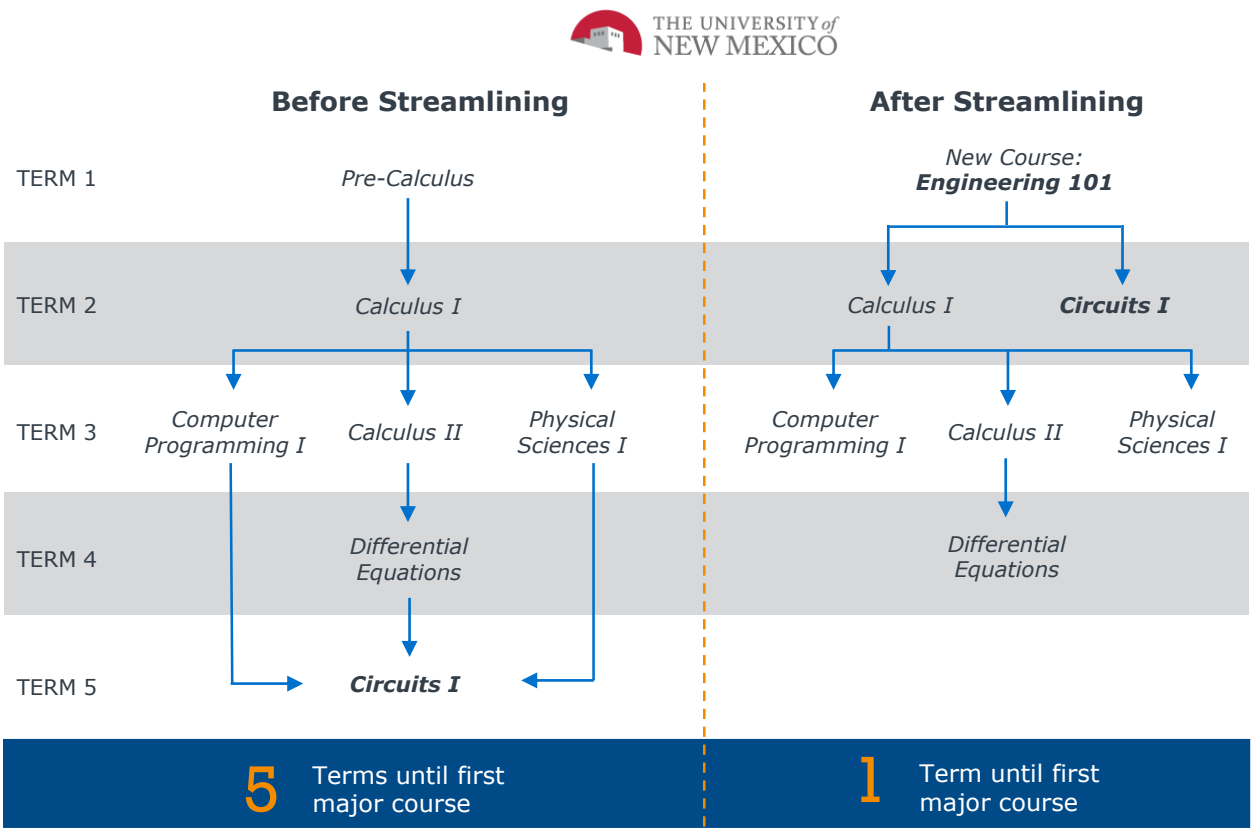
This new sequence helped ensure that students were always one-term ahead in the required math, allowing students who did not have strong math backgrounds in high school to enroll in chemistry. In addition to redesigning the course content, the new courses deployed peer-led learning, multiple, low-stakes assessments, and open educational resources. Initial analyses indicate that students are more engaged in the new courses and completing at very high rates. The creator of this sequence has also proposed a one-credit "bridge" course to the chemistry major, in case some students want to become chemistry majors after taking the new sequence.

Source: EAB interviews and analysis.

Redesigning the Curriculum with Equity in Mind

Across STEM, Reimagined Course Sequencing Reduces Curricular Bottlenecks

Curricular requirements can also create bottlenecks when one course is required for many majors. Restructuring requirements to avoid these curricular-level bottlenecks reduces capacity constraints and ensures majors are more accessible to students. The University of New Mexico used curricular complexity analysis to help academic units identify opportunities for curricular streamlining.



Through this analysis they found that it takes students five terms to complete all prerequisites for the first electrical engineering course. This prompted the department to create a new Engineering 101 course that covered important pre-requisite course content. The changes significantly reduced the complexity of the curriculum while improving student learning outcomes (by providing more foundational engineering knowledge). Students could also progress much more quickly to electrical engineering-specific coursework that relates to their interests and career goals.

Source: Abdallah, et al., "Curricular Efficiency: what Role Does It Play in Student Success?" 2014; Abdallah, Heileman, Kozlick, and Slim, "The Complexity of University Curricula According to Course Cruciality," 2014; EAB interviews and analysis.

Tackling STEM's Diversity Problem

New Introductory Course With Multiple Sections Improves Class Climate

Harvey Mudd College redesigned the computer science pathway to create a more inclusive environment and encourage women to enroll in the major. To achieve this goal, the department created different sections of their introductory course for students with and without prior programming experience. The material taught in both sections was identical but the change in student make-up created a more supportive class environment and helped build student confidence without sacrificing academic rigor.

Multiple Course Tracks Creates Customized Computer Science Pathway

HARVEY MUDD COLLEGE

- Introductory course for students with no prior programming experience
- Introductory course for students with some prior programming experience
- Introductory course for beginner students with a focus on biology
- Course for advanced students which combines first two courses in major

Pedagogical Changes Critical to Improvements in Major Gender Diversity

Expectations Setting

Faculty emphasize that success depends on hard work and asking for help

Practical Application

Coursework is framed as creative problem-solving opportunities using real-life examples

10% → 56%

In 2010, 10% of computer science graduates were women

In 2018, 56% of computer science graduates were women

The department also made pedagogical changes by encouraging collaboration and used more real-world examples to make the content more applicable to students' goals. Moreover, instructors were intentional about ensuring that class time wasn't dominated by a few experienced students and actively encouraged students to enroll in the second computer science course in the sequence. These changes were critical in helping boost the number of female computer science graduates.

Source: "Harvey Mudd Graduates Highest-ever Percentage of Women Physics and Computer Science Majors," *Harvey Mudd College,* May 2018.; Weisul, Kimberly, "Half of This College's STEM Graduates Are Women. Here's What It Did Differently," *Inc.,* May 2017.

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