



## **Mathematical Sciences Department – Natural Sciences – Letters and Science**

The Department of Mathematical Sciences supports a wide variety of internationally recognized Education & Research including strengths in Actuarial Science, Applied Mathematics, Atmospheric Sciences, Algebra, Topology, Probability, and Statistics.

Faculty, staff, and students in the Department collaborate with colleagues from a variety of UWM departments/units along with national and international academic, government, and industry organizations to foster a multidisciplinary approach to complex projects.

External Funding sources include but are not limited to the following: NSF, DOE, NSA, NOAA, Private Foundations, and corporate partners.

An example of collaboration within the College is the Undergraduate Biomath (UBM) program with the Department of Biological Sciences. Undergraduates are trained in a research-intensive fashion on cutting edge problems, and the program has shown significant success in sending students to graduate programs across the nation. External collaborations include the development of next generation cloud parameterizations for the two primary US climate change simulation models, an active collaboration with UW-Madison on the recent strong warming of Lake Michigan during summer months and continuing drops in water levels, and the development of a Midwest Topology Consortium, with UWM as an equal partner with Madison, the University of Chicago, and UIC. Private sector collaborations include work with Northwestern Mutual Life in support of developing Actuarial Science expertise at UWM, while public sector collaborations include the Milwaukee Connected Community, which seeks to improve learning outcomes in mathematics for students in the Milwaukee Public Schools, MATC and UWM by actively working together on curriculum and expectations alignment to increase access and facilitate early college success.

Mathematical Sciences is an integral and essential component of a growing array of areas of investigation including but not limited to: biology, medicine, social sciences, business, climate, finance, sustainability, and advanced materials. This work involves the integration of mathematical expertise in the broadest sense and active interplay with areas of potential application. All of these activities are crucial to economic growth, national competitiveness, and national security.

The discipline has been consistently making major advances in both fundamental theoretical research and in high-impact applications. In doing so, Mathematical Sciences is displaying great unity and coherence as bridges are increasingly built between subfields of research. Such bridges have served as drivers for additional

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accomplishments, as have the many interactions between the mathematical sciences and fields of application. As such, the Department is an integral part of UWM's present and future academic array.

## **Program status and challenges**

The Department of Mathematical Sciences currently has 35 FTE tenured or tenure-track faculty positions, 2 postdoctoral researchers, 4 full-time teaching academic staff, 3.5 administrative support staff, and 0 technology support staff. In 2012, the Department had 63 declared undergraduate majors, 48 Ph.D. students, and 41 M.S. students. In 2012-13, the Department taught more than 50,000 student credit hours (SCH) and had ~\$800,000 in research grant expenditures. Our current SCH/FTE ratio is approximately 300, among the largest on campus, despite the fact that the Department teaches relatively few large lecture courses. The Department relies heavily on approximately 25 FTE of ad-hoc instructors to fulfill its instructional mission. The Department has significant academic and research strengths in foundational mathematics, actuarial sciences, statistics, applied mathematics, and atmospheric sciences.

Mathematical Sciences at UWM is a program verging on a fundamental transition. Our current graduate program is extremely strong, with approximately 2 PhD students per active math faculty member (defined here as tenured with 30 or less years of service). However, significant turnover in our faculty is projected by 2020 or soon thereafter, as indicated in the figure below, with the number of active math/statistics faculty members (excluding atmospheric sciences) dropping from the current level of 26 to 15 in 2022. Given the long lead times for faculty hiring and progress to tenure, this projection must be taken as the fundamental challenge underlying academic planning. In the Department, active faculty defined in this manner do the core of the service work, including supervision of vast majority of PhD students. Assuming a "business as usual" relationship between PhD students and active faculty, the looming reduction in active faculty strongly suggests the PhD program in mathematical sciences is at risk. To address this, **we must fundamentally restructure our activities, and develop a New Mathematical Sciences Program at UWM.** Given the looming changes facing academia, the answer cannot be merely replicating what exists. Hence, we must design what we as a Department and what UWM as an institution really need.

Our vision for the program is driven by three key philosophies: **Access**, **Excellence**, and **Impact**, all of which fit into the Chancellor's vision of commitment to excellence, powerful ideas, community and global engagement, and collaborative partnerships. In re-visioning our program, we will measure ourselves not by whom we exclude, but rather by whom we include and how they succeed. We will pursue research and discovery that benefits the public good. Finally, we will assume responsibility for our part in building the economic, social, and cultural vitality of the community and the state.

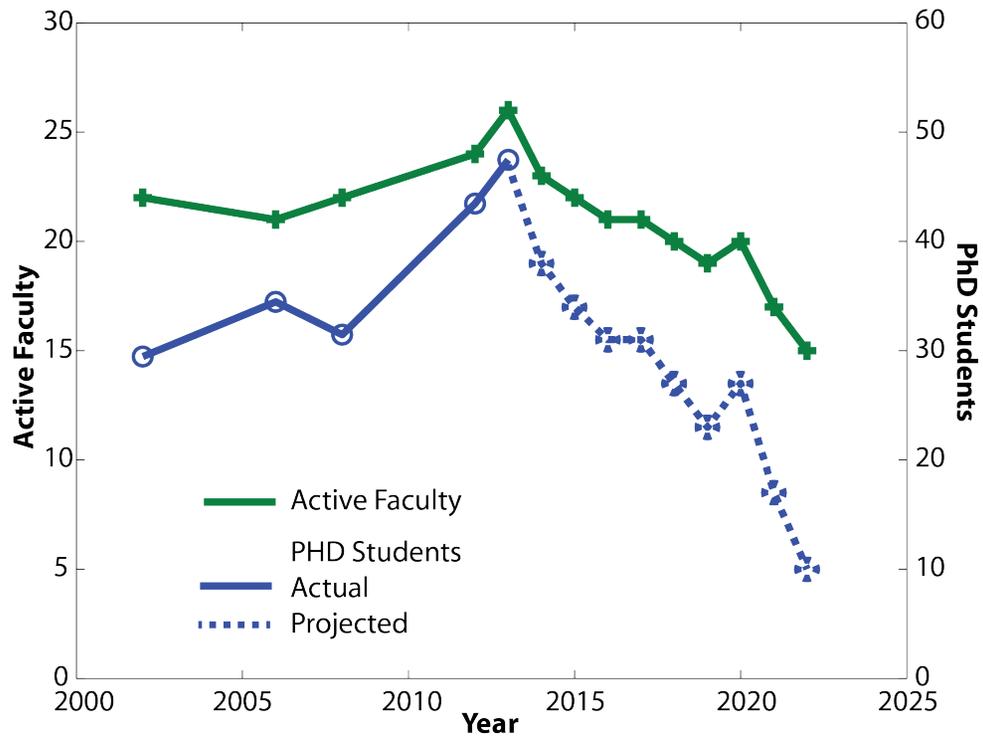


Figure: Historical and projected active faculty and “business as usual” PhD Students in the Department of Mathematical Sciences. Future active faculty numbers are basically set by the current Department demographics. “Business as usual” assumes the relationship (regression) between active faculty and Ph.D. students over the past decade carries into the future.

Our plans for 2020 are driven by four fundamental goals:

### Remediate and Engage

**Action:** *Be the national innovator in scalable developmental math education, and bring this expertise to K-12.* We have recently embarked on a complete redesign of the developmental program at UWM. We seek to implement change on a scale similar to what the Carnegie Foundation has accomplished *in total* at 30+ institutions over a 5 year period, *all in a single year.* Our program revisions focus not only on the structural and curricular problems of traditional developmental math courses, but also the substantial socio-emotional and psychological hurdles many students face. Our revised program courses are designed to challenge certain beliefs that many developmental math students share: that they are not “math people,” that “people like me don’t belong here,” and that the class is really not about or for them. We refer to these new course sequences as pathways, following the STATWAY and QUANTWAY initiatives developed by the Carnegie Foundation, as well as the Math Literacy movement emerging out of the American Math Association of Two Year Colleges.

Drawing on a research base developed over many years in education, our goal in offering these pathways is to teach math content along with a new set of strategies to help students persist and succeed academically. At its core is the fundamental belief that students will have greater motivation to succeed and persist if their mathematics study is engaging, meaningful, relevant and useful. In other words, we need to provide an educational experience that students will value. If we do this, they will engage. Doing so, we include significant amounts of writing, group work, and other strategies proven to build a better college student into these pathways. The goal: a student not only more likely to persist to degree, but one ready to function at a higher level of attainment.

By 2020, the Department of Mathematical Sciences will have in place a professional instructional staff, with appropriate support, engaged in developmental math and pursuing a single goal: Commitment to the success of each student that UWM chooses to accept. We will use active learning pedagogy, enhanced by technology, coupled with extensive instructor training and the development of course-specific Faculty Inquiry Groups to continuously drive program improvements. Further, we work with our partners in the Milwaukee Connected Community, MPS and MATC, to spread the impact of what we learn about developmental mathematics to K-12. Our Department will become a force for change as UWM transitions to a “majority minority” campus by 2020.

**Indicators:** Year-2 retention of students who enroll in developmental mathematics (GER QL-A level and below) will be higher than that of students who test out QL-A level mathematics. We will garner at least two major private foundation/government grants in support of the program by 2020.

**Resources needed:** 4-5 additional full-time teaching academic staff; 1 additional classified academic staff engaged in assessment and advising, along with office, active-learning classroom space, and collaboration space. These academic staff will replace current part-time instructional staff at minimal extra cost, providing a level of professionalization and institutional engagement currently lacking in this program.

## **Facilitate STEM**

**Action:** *Build a calculus program that drives attainment and persistence.* The current state of the calculus program leaves many students disillusioned, and is characterized by extensive use of part-time instructors at the lower levels and low student persistence from course to course in the sequence. It is this realization that drove the Department to engage in the HHMI process aimed at reforming pre-calculus and calculus I, and which drives our vision for the calculus program in 2020. *For UWM to meet its research goals and become a STEM oriented campus, calculus must function effectively.* This will be accomplished by following the model used by the University of Michigan during the 1980’s and 1990’s to rebuild their calculus program: First, foundational mathematics (algebra, analysis, and topology) will be assume ownership of the calculus program. This ensures no more “passing the buck” as to the state of the program, as future faculty positions in foundational math will be tied to the success of calculus. This is reciprocal, of course – without investment, faculty resources to improve calculus are not sufficient. Secondly, there will be significant involvement by appropriate faculty in teaching calculus as well as in program oversight, driven by a “calculus executive committee” consisting of faculty members from each of the three areas of foundational math and the calculus coordinator. These faculty members would commit to a 3-year term on the committee, actively reshaping the calculus sequence, mentoring TAs, and teaching calculus each semester. Third, a re-vitalized rotating 3-year visiting assistant professor program will be used to augment faculty instruction, supplying qualified energetic and engaged instructors to calculus. Three of these visiting assistant professor positions will be in the areas of foundational math. Finally, all courses will be learning focused and outcome measured, with outcomes explicitly designed to serve the aspirations of the student population we serve. The program will be structured to adhere to Mathematical Association of America’s 2013 best practices:

- a. *Collegiality and shared sense of responsibility for Calculus*
- b. *Attention and responsiveness to local data, including effectiveness of placement procedures and retention rates*
- c. *Well-run and well-utilized tutoring centers with aggressive encouragement for all students to use this resource*
- d. *Strong programs for training Graduate Teaching Assistants*
- e. *Promotion of active learning strategies and rigorous courses*

Coupled with expanded outreach activities by faculty, along the lines of the current Math Circles program currently serving roughly 25 area high school students on a weekly basis, ownership of calculus in this fashion will provide a means to build the Department's research landscape that far exceeds the impact of traditional academic activities for our University and regional stakeholders.

**Indicators:** A doubling of the number of students who pass Math 233 (Calculus III) each year by 2020, with enhanced attainment as measured by appropriately designed assessment instruments.

**Resources needed:** Six 3-year term visiting assistant professors full-time engaged in teaching calculus (3-4 sections/year), plus maintenance of the foundational mathematics faculty at a minimum of 12 lines (at least 4 each in topology, algebra, and analysis), along with office, active learning classroom, and collaboration space. The visiting assistant professor positions will replace part-time senior lecturers in the instructional staff at modest additional cost, providing a level of academic engagement, expertise and professionalism lacking in the current academic environment, with the added benefit of raising the research profile of the department.

## **Embrace Mathematics**

**Action:** *Build undergraduate programs that bring students into the mathematical sciences.* Mathematics for mathematics sake is a hard sell for undergraduates at research-intensive universities, as the most recent NRC survey shows that only 1% of undergrads who enroll in Calculus I do so intending to major in mathematical sciences. However, it is vital for both UWM and Milwaukee that we draw students into our major-level programs. For example, Northwestern Mutual Life (NML) will be hiring 1000 new employees as they expand their downtown facilities by 2017, a substantial fraction of which will be actuarial or financial math oriented; the new Schools of Public Health and Freshwater Sciences need a steady stream of quantitatively literate undergraduates to fulfill the potential of their graduate programs; and there is an ongoing need for rigorously trained teachers to strengthen secondary mathematics programs throughout Wisconsin. We will pursue a number of different routes to making mathematical sciences a more attractive major for prospective students, including:

- a. *Simplification of the mathematical sciences major.* Our current major is complicated, consisting of a number of different tracks, which has the effect of confusing students and spreading efforts over a too broad range of courses. The undergraduate major in mathematics will be revised to consist of introductory courses (4 semesters of calculus), transition courses (proof, basic algebra and analysis courses, and a modeling course), a two-semester sequence to encourage in-depth student exploration of a single topic, and a two-semester research experience similar to what is currently done in the biomath program.
- b. *Increasing support of the actuarial science program.* The actuarial science program at both the undergraduate and graduate levels is very popular, very necessary for our future economic development of Southeast Wisconsin, and very understaffed. There are currently roughly 75 declared and intended majors in the undergraduate program, along with 6 masters students and 4 PhD students, but only two faculty members

and one academic staff. This level must be increased to 4 faculty members by 2020. Doing so will ensure Center for Actuarial Excellence (CAE) designation, which will facilitate recruitment of both local and tuition-paying international students.

- c. *Support and interact with CEAS.* Applied Mathematics and Computer Sciences is a growing academic program shared with CEAS that demonstrates the Department's commitment to interdisciplinary education. The proposed academic plan seeks to expand this commitment, as closer collaboration with our partners in CEAS at all levels benefits UWM and our stakeholders throughout the region.
- d. *Build feeder programs to 3+2 masters programs in System Sciences, Freshwater Sciences, Public Health, and Financial Mathematics.* The mathematical sciences span a broad range of potential in-roads to other fields, and these need to be supported to help enhance the differentiation of UWM's program array relative to other Universities. We will provide the quantitative expertise to ensure the success of the Natural Sciences System Science initiative. Given that Public Health and Freshwater Sciences are unique within the state, supporting those programs with well-designed undergraduate feeder programs leading to accelerated degrees is sensible, and would link our department to those units more closely facilitating research collaborations as well. A 3+2 Financial Mathematics Masters is a natural extension of the actuarial science program, and is an appealing and necessary addition to UWM's programmatic array.

**Indicators:** Program revisions completed as stated above. Increase the number of declared majors in the Department from current levels of 60 to 100 by 2020. Obtain CAE designation, and expand actuarial program including active recruitment of tuition-paying international undergraduates. Major development grant/gift from NML and/or other partners to support continued build-out of actuarial and financial mathematics programs.

**Resources needed:** Two additional tenure-track faculty positions (one clinical and one traditional) in actuarial science to solidify CAE designation. The clinical faculty position comes with minimal cost, as it would replace a teaching academic staff position within the Department. Two additional faculty positions in financial mathematics/applied probability and statistics; and faculty positions explicitly linking the department to other units as outlined below.

## **Be Different. Be Better.**

**Our goal:** *Build a graduate and research program that is uniquely Milwaukee.* Our current graduate/research programs have several areas of strength. Atmospheric Science has a very strong funded research program, with Innovative Weather and ties to SFS as further scaffolding to build upon. The Department has traditional academic strengths in Foundational Mathematics, particularly in algebra and topology. Finally, there is a core of faculty actively interacting with Biological Sciences through the Undergraduate Biomath program that can be built upon. However, envisioning the future involves asking what UWM and our external stakeholders truly need. As faculty demographics suggest the current graduate/research program may be unsustainable, a new future must be envisioned. However, this cannot be simply a replication of the traditional research university mathematics graduate program. Such a program is not consistent with the demands of our stakeholders, whether the citizens of Wisconsin or our public and private partners. Specifically, it does not provide the differentiation necessary to make UWM irreplaceable within the state, let alone the nation, nor would it allow us to effectively compete for funding or the best students.

Looking forward to 2020, we envision a “barbell”-type approach to transforming the research profile of our department. One end of the barbell seeks to preserve the core of mathematics within the department to insure our graduates have the expertise to compete in the future academic job market, and explicitly tied to the re-envisioning of the calculus program noted above. This will allow the department to offer the graduate-level courses

necessary to maintain an active graduate program. The other end of the barbell consists of using new faculty positions to much more aggressively pursue applications and collaborations with internal and external partners, ultimately seeking to fulfill several particular design aspirations: conduct useful research, fuse intellectual disciplines, and value entrepreneurship. We envision the following as areas of future research hires/interests:

- a. *Systems Science Integration I: Mathematical modeling and drug discovery.* There are extensive opportunities for research using mathematical models to help discover drug targets for disease, network-based models to examine combinatorial drug targets, and functional models of drug delivery to particular targets. The presence of MIDD within the Department of Chemistry and faculty members within MathSci currently with research expertise in this area makes pursuing interdisciplinary hires in this area a natural extension for the department's expertise.
- b. *Systems Science Integration II: Biostatistics and the mathematics of infectious disease liaising with SPH.* Research within the biomathematics area including the public health arena is heavily mathematical, driven by the complexity of the underlying systems and the need to process large quantities of data. These areas are natural extensions to the Department, would provide explicit research links of relevance to our academic partners and community stakeholders, and are important to society as a whole.
- c. *System Science Integration III: Biomathematics and climate science positions liaising with SFS.* There is a demonstrated need for both physical and quantitative expertise to augment current strengths in ecology and the various sub-fields of biology, both within the College and with SFS. These positions will augment and extend the research strengths of the atmospheric science and biomath groups, in particular strengthening expertise in air-sea interactions, the physical end of the water cycle and its variability due to climate change, and more general cloud/climate processes, as well as active areas of bio-mathematical research such as population dynamics and reaction-diffusion type systems.
- d. *Supporting innovation with quantitative expertise.* Entrepreneurship requires access to quantitative expertise. Supporting innovation, whether through the Milwaukee Water Council, MiKE, or other incubators, lies outside the realm of the traditional academic reward system. As we move to 2020 and beyond, we are optimistic that the department can evolve towards a "Quantitative Idea Distillery" that will actively engage partners in the community to provide expertise to accelerate the development of innovative ideas. This will support campus initiatives in big data, imaging, and high performance computation.

**Indicators:** At least 5 shared faculty lines with other departments/units by 2020, with 8-10 major funded (collaborative) projects within the department (up from 5 currently). Re-configuration of the integrated portions of the graduate program towards a more research-driven, interdisciplinary solution-based model, with upticks in funded research assistant and research postdoc activities.

**Resources needed:** 2-3 new faculty lines, as well as interdisciplinary research space. Additional lines beyond this will replace faculty retirements.

Putting this plan into action will require new vision from the Department, most notably regarding the essential role of service to our partners and stakeholders. We recognize that this service will take different forms; engagement with early career undergraduates, outreach activities to our K-12 partners, and efforts to engage research partners at UWM and in the larger regional community. We also recognize that the freedom to build our research landscape comes with the responsibility to serve our students and stakeholders. We welcome these challenges, and look forward to the opportunity to reshape Mathematical Sciences at UWM.