



University of Colorado **Boulder**

2017 Program Review

Department of Mathematics

Academic Review and Planning  
Advisory Committee Report

Approved

*Paul M. ...* 03/20/2018

Provost and Executive Vice Chancellor for Academic Affairs: Date

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## Process Overview

The review of the Department of Mathematics was completed in accordance with the 2017 review guidelines. The Academic Review and Planning Advisory Committee (ARPAC) conducts and writes the final reviews of all Boulder campus academic units. Mathematics completed a self-study in December 2016. An internal review committee of two CU Boulder faculty members from outside of the unit checked the study and issued findings in February 2017. The internal reviewers generally found the report fair and accurate and noted several issues for subsequent exploration by the external reviewers and ARPAC. The external review committee, consisting of two experts within the discipline from outside of the University of Colorado, visited the unit over April 20-21, 2017, reviewed relevant documents, and met with faculty, students, staff, and university administrators. Internal and external reviewer comments and recommendations are cited at appropriate points throughout the report. This public document reflects the assessment of and recommendations for the Department of Mathematics as approved by ARPAC.

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## Unit Overview

The campus's standardized description of the unit is available on the website of the Office of Data Analytics (ODA) at

<https://www.colorado.edu/oda/institutional-research/institutional-level-data/information-department/academic-review-and-planning>.

ODA updates the profile annually in the fall semester. This report cites data posted in October 2016, reflecting the state of the Department of Mathematics as of the academic year (AY) 2015-16. Updated data provided by the department is included where appropriate.

Mathematics faculty publish monographs and articles in the field's top publications, they engage their peers at conferences, and collaborate with natural sciences and humanities units on campus. Mathematics counted 376 undergraduate majors in AY 2015-16 and 77 minors (highest in the units under review), along with 67 graduate students (three masters, 64 doctoral). Undergraduate major numbers have grown to 387 according to 2017 ODA reporting, reflecting a 19% increase over five years, while the graduate student population has remained stable at around 70 over the same period. In fulfilling their teaching mission, Mathematics faculty members generate the second highest number of student credit hours (SCH) of any CU Boulder unit (38,373 in AY 2015-2016). The department's lower-division undergraduate teaching is a bright star, and has been recognized nationally, including with a 2016 five-year grant of \$3,000,000 (split among four institutions) that was awarded to study the implementation of sustainable active learning strategies in the sequence of Precalculus, Calculus 1, and Calculus 2. In spite of these strengths, however, the Mathematics self-study and the internal and external reviewers all note that the unit must address longstanding climate issues to ensure continued excellence and improvement.

Personnel  
and  
Governance

According to the Mathematics self-study, the department has 26 tenured and tenure-track (TTT) faculty (14 full professors, six associate professors, and six assistant professors), two visiting professors, eight instructors, and 18-25 lecturers (numbers vary by semester depending on teaching needs). These numbers reflect two new TTT faculty hires since the 2015-2016 ODA profile. According to the dean of the College of Arts and Sciences, there are also six teaching post-doctoral fellows and four staff members, including one assigned as an IT professional.

Department chairs typically serve a three-year term. After a failed election for chair in 2016, a temporary outside chair was brought in at the department's request. Subsequently, the department held a successful election in 2017. A separate associate chair heads each of the graduate and undergraduate committees. An elected executive committee with broad responsibilities comprises four voting members drawn from tenured faculty, with the chair and associate chairs serving ex officio as non-voting members. The executive committee also functions as the annual merit and salary evaluation committee. Junior faculty and instructors are not represented in these matters, and the external reviewers report a perception in the department that processes related to merit raises are neither transparent nor fair. In other respects, the bylaws appear to conform to campus norms.

According to ODA data, assistant and associate professors' salaries are above peer averages (105% and 102% respectively); full professors' salaries lag significantly behind (83%).

Research  
and  
Scholarship

The department's work addresses a robust and diverse research profile. The self-study describes faculty members'

research areas, publications, and conference participation. Mathematics faculty have organized themselves into nine topical groups enumerated and described in the self-study as Algebra, Algebraic Geometry, Analysis, Differential Geometry, Logic and Foundation, Mathematical Physics, Number Theory, Probability, and Topology.

It is difficult to evaluate Mathematics' research volume in purely quantitative terms, as quirks of the discipline's publishing ecosystem lead to lower rates of certain types of publications field-wide. While the research productivity of individual faculty varies, the Office of Data Analytics ranks the department highly in the campus context in terms of monograph and edited book production (2<sup>nd</sup> of 8 units in the review cohort). By contrast, Mathematics ranks at the bottom of the review cohort (8<sup>th</sup> of 8) in journal article production (departmental average of slightly more than one article per year per faculty member) and conference presentations (slightly over two per year per faculty member). To better understand the relevance of these metrics, the self-study includes the following statement from the American Mathematical Society on the productivity of top mathematicians:

*A study of the 40 mathematicians winning Sloan Fellowships in 2005-2006 shows that 70% published an average of two or fewer articles per year in the five years preceding their award... Even more senior mathematicians have modest publication rates. Of the 22 mathematicians receiving Guggenheim Fellowships from 2002-2006, half published an average of two or fewer articles per year in the five years preceding their award. These two groups represent an exceptional group of highly recognized mathematicians.*

By this accounting, Mathematics appears to achieve an appropriate level of research output; however, it is difficult to

use comparative data to assess the department's research productivity. The self-study and external reviewers concur that mathematicians write fewer articles and that the field's publishing habits do not align well with the metrics campus research entities use for internal and external comparisons. According to American Mathematical Society reports cited in the self-study, by its nature, pure mathematics research leads to fewer publications, many of which are longer and single-authored. Publications take longer to arrive in print, and scholars cite articles less frequently than in similar fields, in part because much research is shared pre-publication. Comparisons with peer schools, where ODA data places Mathematics relatively low, are also problematic because only two other departments in CU Boulder's peer group—34 American Association of Universities (AAU) public institutions—have divided pure mathematics and applied mathematics into separate departments, as CU Boulder has.

The department has seen external funding grow, a trend the faculty intend to bolster, the self-study reports. The level of Mathematics' extramural funding from the National Science Foundation, the National Security Agency (NSA), the Simons Foundation, and other groups has increased since the 2010 program review, with 20 of 26 tenured and tenure-track faculty receiving extramural research funding over the seven-year period. The self-study includes the following from the American Mathematical Society's 2008 Statement on the Culture of Federal Support for Academic Research in Mathematics:

*In FY2006, across all fields of science and engineering, the Federal government provided about \$260,000 per academic researcher. By field, this breaks down to \$360,000 per academic researcher in Computer Science, \$140,500 per academic researcher in the Physical Sciences, and \$430,000*



*per academic researcher in the Life Sciences. By contrast, in 2006 the Federal government provided about \$47,000 per academic researcher in Mathematics.... When compared to other fields of science and engineering, opportunities for external funding in mathematical sciences are very limited. The vast majority of mathematicians receiving Federal support have just one, single investigator, NSF grant.*

While this statement is not current, it helpfully contextualizes the limited external funding opportunities that pure mathematicians face, presenting in a more positive light the comparison group cited by ODA data. That said, the most recent ODA data show an average of only \$9000 in extramural funding per tenured/tenure-track faculty member for the latest reporting AY. The five-year numbers are a bit better: accepting the self-study's enumeration of twenty faculty members receiving funding, the average annual amount for each of those twenty faculty is \$14,250. In the self-study, Mathematics expresses an intent to further nurture the positive trend of growing extramural funding underway since the 2010 review.

#### Undergraduate Education

Mathematics offers an undergraduate B.A. degree, an undergraduate minor, and a combined B.A./M.A. option. The department has recently agreed—after some friction with the College of Arts and Sciences and the Department of Applied Mathematics—to cooperate on developing an undergraduate statistics degree, though this offering is not reflected in currently-available ODA data. In general, the department's strong undergraduate curriculum shows a commitment both to the major and to extensive service teaching (90% of undergraduate SCH).

Mathematics moved to a smaller class-size model twenty years ago, and has over the years developed a pedagogy that places

it at the forefront of undergraduate mathematics teaching nationally. In addition, Mathematics has transformed its delivery of first-year courses over the last 20 years, and is nationally recognized for these achievements, as indicated by two significant grants to study implementation of approaches including smaller class sizes, flipped classroom teaching, and active-learning classes. The department's approach depends on smaller class sizes and classrooms specifically adapted to the active learning environment; at this time, such spaces are not generally as available to the department as they ought to be.

For teaching lower-division undergraduate courses, the department relies heavily on non-tenured/tenure-track faculty, 18-25 lecturers per semester. Because classes are capped at 31 students, numerous sections are required to accommodate the large, and increasing, undergraduate population.

Administering the lower division courses has proved challenging, and Mathematics has recently hired an instructor as its lower division curriculum director who runs the program as one-third of a 75% teaching load. ODA reports that 14% of SCH were taught by tenured/tenure-track faculty in AY 2015-2016; 15% in 2016-2017. To raise this number, Mathematics is arranging for TTT faculty to teach two sections of a lower-division class each semester and supervise the instruction of the other sections.

A recent increase in majors and accompanying recalibrations may have contributed to undergraduate criticisms of the department's course offerings, content, and teaching style. While 90% of SCH generation comes from service teaching, the department must remain mindful of the 376 majors and 77 minors counted in AY 2015-16. The internal review student surveys show significant reason for concern about how

tenured/tenure-track faculty deliver their courses. The surveys include an atypical number of negative comments, which indicate that some TTT faculty are not ideal instructors for the classes currently offered, and also suggest that faculty need to communicate better with each other about what they are teaching in their classes to avoid burdening majors and minors with duplicative material over their course of study. ODA 2016 senior survey results for Mathematics show low rates of satisfaction on all measures; the department consistently ranks fifth of the five units considered. FCQs are also the lowest of the units under review, although there is an upward trend in the raw numbers.

On a positive note, Mathematics students tend to stick to their decision to pursue the major. ODA data shows 93 B.A. degrees awarded in AY 2015-2016 and a median time-to-degree of four years. A reasonable share of students who declare Mathematics as their first major are retained within the major, and the retention rate of these students at CU Boulder overall is above the norm. ODA data for the undergraduate cohorts entering CU Boulder between 2007 and 2010 shows that, of students declaring Mathematics as their first major, 43% graduated with a Mathematics major within six years. The comparable figure for all-natural sciences majors in the same period was 48% of students graduating within six years in the major that they first declared. Of those declaring Mathematics as their first major, 68% graduated with an A&S degree (any major) within six years, and 73% graduated from CU Boulder overall (any college). Campus-wide, the six-year graduation rate for these cohorts was 70%.

Graduate student responses to the program remain generally positive, though a lack of resources has led to long degree completion times. Graduate student numbers (roughly 70) and

SCH have remained relatively stable during the review cycle. The unit offers three graduate degrees, an M.A., an M.S. (in collaboration with APPM), and a Ph.D. There is currently only one student enrolled in the M.A. (self-study numbers; ODA data shows three). Though roughly 50% of students who enter the Ph.D. program end up leaving with an M.A., student surveys generally show a high level of program satisfaction. The sizable undergraduate teaching load has contributed to the department's difficulty scheduling graduate courses. Because the department shoulders heavy undergraduate teaching responsibilities, TTT faculty are not consistently able to offer sufficient advanced coursework to prepare Ph.D. students for comprehensive exams, and much of the department's advanced teaching is delivered as one-on-one tutorials. This fact, combined with low stipends and Boulder's high living costs, contributes to longer than optimal degree completion times, and the relatively high attrition rate for the Ph.D. These conditions have a negative impact on the department's ability to recruit students in competition with other high-level programs.

Mathematics is authorized to offer limited student funding, including 110 semester-long teaching assistant (TA) positions and one year-long graduate part-time instructor (GPTI) position. Mathematics also funds students through research assistantships (two at the moment), the Chancellor's Fellowship (one), the Diversity Fellowship (one), the GI Bill (one), and teaching appointments in other departments or in the Division of Continuing Education. Other graduate students are employed and/or self-funded.

Currently, junior faculty handle the bulk of Ph.D. advising. According to the internal reviewers, six assistant professors advise 40% of the Ph.D. students while accounting for only

26% of the TTT faculty: “The average number of Ph.D. students advised by assistants is 3.16 compared to 1.16 for associates and 1.6 for full professors.”

Perceived advising disparities among graduate students may have contributed to the high attrition rates among women and other underrepresented groups that the self-study acknowledges plague the Ph.D. While there were several positive comments about camaraderie and individual faculty quality, an overwhelming number of comments suggest that communication, mentoring, and advising are highly uneven. Graduate students have diagnosed pervasive biases on the part of some faculty based on gender and ethnicity, and have also suggested that the unit’s stated commitment to diversity is not always reflected in its behavior and actions.

Graduate student placements vary, and several alumni have followed non-academic career trajectories, especially into the information technology industry. The department does not have robust graduate student outcomes records, although they plan to improve future tracking. Graduate student surveys mention that more attention should be paid to mentoring students seeking non-academic employment.

Space  
and  
Infrastructure

The self-study notes that Mathematics’ current space and staffing are modest compared with most campus units and have not kept pace with a growing undergraduate population, a group that the core curriculum requires the department to teach.

The self-study mentions that the department currently lacks access to classrooms adapted to Mathematics pedagogy (movable desks, dry erase boards on all four walls). The self-study requests two classrooms they can renovate for this purpose.

Given the large number of lecturers and TAs that the department employs, there is a constant demand for more office space than is currently available. Seven Mathematics instructors share four offices, and it is difficult to find additional spaces for lecturers, post-doctoral fellows, and frequent visiting scholars.

#### Inclusive Excellence

Mathematics has reconstituted its diversity committee as of fall 2013. The self-study describes several initiatives that the department is undertaking to improve student recruitment and retention, including faculty and staff training, peer mentoring, better graduate student funding, and collaboration with other campus entities including the Leadership Education for Advancement and Promotion program and the CU Boulder Gender and Sexuality Center. The department strives to diversify faculty recruiting to improve gender balance and increase the number of faculty from underrepresented groups. This goal is stymied by the systemic paucity of underrepresented minorities and women completing Ph.D.'s in Mathematics. To address this problem, the department has redesigned preliminary exams and increased academic support for underrepresented minorities and women. The department's diversity and graduate committees are collaborating to improve retention among these groups. While the self-study indicates awareness of these issues, numerous graduate students surveyed by the internal reviewers perceived pervasive gender and ethnicity biases, with some indicating that unit diversity efforts do not always appear sincere.

According to ODA data, the number of Mathematics faculty categorized as international ranks highest among units under review in 2017, second highest for underrepresented minority faculty, and in the middle for gender balance and broader definitions of ethnic diversity. The undergraduate student

population again shows a high ranking in numbers of international students, with lower rankings in all of the other areas. Aside from a 5% decrease in female students over the last five years, Mathematics shows impressive increases in the number of international and underrepresented minority students. At the graduate student level, the numbers are less positive, with a significant decrease especially in the number of individuals from underrepresented minority groups.

Climate      The department continues to deal with problems caused by a small number of senior members who engage in uncivil conduct toward colleagues, staff, and students, despite ongoing efforts to address longstanding internal climate issues. The climate's hostility is addressed in a consultant's report included with the self-study and in some of the responses to the internal reviewer administered student surveys. According to the external review report, "most everyone in the department agrees that a small number of people's incivility and unprofessionalism makes life unpleasant for everyone." This behavior may violate the CU Boulder policy on the Professional Rights and Duties of Faculty Members and Roles and Professional Duties of Department Chairs, and the University of Colorado Code of Conduct. The external consultant brought in by the interim external chair mentions "shaming, verbal abuse, etc." by certain faculty members. Staff also report verbally abusive behavior and a lack of respect from faculty members. Altered bylaws are among the external consultant's recommendations that would help reduce the concentration of personnel power among senior faculty; this recommendation is discussed further below. While the external consultant's report includes a detailed survey indicating that negative internal climate issues arise from conflicts between incompatible personalities rather than characteristics like gender or ethnicity, some of the written responses to the

internal reviewer administered student surveys suggest that some faculty harbor biases against women and people of color.

The self-study and the external reviewers both mention that longstanding morale issues followed from the division of Mathematics and Applied Mathematics into separate departments. The external reviewers note that Mathematics' assistant and associate professors are more willing to collaborate with their colleagues in Applied Mathematics than are full professors, an encouraging sign that, in the future, the relationship between the departments may become more harmonious. Recent cooperation between Mathematics and Applied Mathematics to co-administer the newly approved B.A. in Statistics may also alleviate tensions among Mathematics, Applied Mathematics, and the college.



## Past Reviews

Mathematics last underwent review in 2010. That review's recommendations have been included in this cycle's self-study as part of the department's current strategic plan. At the time, ARPAC recommended that the department develop a faculty hiring plan, which has had limited success, with a net gain of one member since 2009. The self-study notes that recent hiring (all assistant professors) has produced a productive cohort of younger faculty, but more faculty are necessary to address teaching demands at all levels. In addition to hiring issues, space needs have been, and remain, a pressing department priority, given growing numbers of students who are served in smaller-sized classes as well as challenges in providing adequate office space for graduate students and instructional faculty.

In many respects, Mathematics has responded to ARPAC suggestions from the last review cycle. For instance, Mathematics has coordinated to have more of its faculty members engaged on college and campus committees. Collaboration between Mathematics and Applied Mathematics was an issue in 2010; the current self-study includes evidence of increased cooperation, although some matters still need addressing. The department continues to work to expand postdoctoral funding, and, responding to an ARPAC request, has followed through on clarifying criteria for merit evaluation, salary adjustments, and promotion. The self-study identifies sufficient TA position funding, to allow for expansion of the Ph.D. program, as a persistent concern.

## Campus Context

Mathematics faculty members teach almost the entire undergraduate population, providing lower-division math classes that enroll students from all majors, as well as upper-division classes that serve students in engineering and the physical and social sciences. The department also designs courses to serve students in specific programs, putting together an impressive list of cross-disciplinary teaching and research involving Applied Mathematics, the School of Education, the College of Engineering and Applied Science, and units in the humanities and in the natural sciences.

## Disciplinary Context

While other units under review this year have recognized national and international profiles, it is more difficult to determine where Mathematics stands. CU Boulder's institutional research ranks the department in the middle of peer institutions (the self-study includes an exhaustive list), but Mathematics makes the case, and the external reviewers concur, that the metrics fail to account for the uncommon situation of having separate pure and applied mathematics departments. Some individual faculty members have national and international visibility and are productive by the standards of pure mathematics departments, with extramural grant support (NSF, NSA, Simons Foundation, etc.) at a level that, while in need of further improvement, has increased since the last review.

## Analysis

Despite strengths that include a record of innovative undergraduate teaching and a strong cohort of junior faculty doing important research, Mathematics faces significant challenges. ARPAC notes uneven research productivity in publications and funding among Mathematics faculty. The unit also evinces problems with teaching and mentoring, as indicated by student feedback. ARPAC strongly believes that the toxic atmosphere created by the actions of a small number of faculty has harmed and continues to harm Mathematics' climate and standing. For this reason, improving the department's climate should be the priority. ARPAC urges the department to use existing processes and resources to address these issues, not only rewarding productive colleagues through existing structures for merit, reappointment, promotion and tenure, and post-tenure review, but also using these same processes appropriately to report and censure inappropriate behavior, lackluster teaching, and/or research productivity. The department should also feel free to pursue potential sanctions under the CU Boulder policy on the Professional Rights and Duties of Faculty Members and Roles and Professional Duties of Department Chairs; the University of Colorado Code of Conduct; and the policies of the Office of Institutional Equity and Compliance.

## Internal Climate

Perspectives on the health of the department's climate are mixed. The external reviewers note that the climate for research in the department is excellent, with many opportunities for sharing both within the department and with external visitors and on-campus colleagues. On the other hand, the department self-study, and internal and external reviewers, all note that personality issues have created longstanding problems. ARPAC commends Mathematics for actively seeking help, including engagement with an external consultant. ARPAC urges Mathematics to follow through on the consultant's suggestions

to improve problems with communication, with relationships among faculty, students, and staff, and with transparency. A lack of transparency is especially pronounced surrounding how the executive committee is selected and how it conducts personnel-related work. ARPAC concurs with the external reviewers that any plan to improve interpersonal relationships within the unit needs to be fully supported by both the unit and the college. In addition, ARPAC supports the following recommendation from the external review committee:

*We recommend the department consider creating a document that clearly spells out a policy on standards of community behavior within the department, and implementing procedures to enforce its content. Some of the material in CU's Professional Rights and Duties of Faculty Members and Roles and Professional Duties of Department Chairs could serve as a template or starting point for this document. A policy that is strongly endorsed by the department's members would strengthen the Chair when correcting incivility among the faculty and other members of the community. We feel it is important for the department to make clear to everyone (faculty, students and staff) that certain behaviors will not be tolerated, and to try to address them swiftly when they appear. We feel that this problem can only be solved through a concerted effort by a majority of the members to call out unacceptable behavior, supporting each other when this takes place.*

Relevant information on appropriate conduct from the policy on Professional Rights and Duties includes the following statement ([https://www.colorado.edu/bfa/sites/default/files/attached-files/PRDJanuary16\\_2013.pdf](https://www.colorado.edu/bfa/sites/default/files/attached-files/PRDJanuary16_2013.pdf)):

*As an academic colleague, a faculty member has professional obligations and expectations that derive from membership in*

*the community of scholars. Prominent among these obligations and expectations is collegiality between faculty members and other academic associates. Collegiality, expected of each faculty member, includes civility, mutual respect, common courtesies, personal accountability, and willing contributions to the effective functioning of the academic unit.*

Tolerating a toxic climate is a disservice to the department and should be reflected in formal evaluations at all levels, including annual merit evaluation, promotion and tenure, and post-tenure review. According to the policy on Professional Rights and Duties:

*Collegiality (See section II.C, "Ethical Principles") contributes to a cooperative, harmonious, and productive work environment in an academic unit. Merely irritating conduct, evidencing a lack of collegiality, shall not alone be the basis for imposing a sanction more severe than a confidential reprimand of a faculty member. However, the Supervising Administrator may impose a more serious sanction if he or she determines that the lack of collegiality is of such severity or duration that it compromises the effective operation of the academic unit or substantially interferes with the work of one or more of its faculty members, staff, or students.*

Mathematics must act forcefully on violations of professional behavior, including imposing sanctions if necessary. ARPAC will need to see updates on the implementation and success of these policies in formal written responses to this review document.

Other departments have taken steps to prevent hostile climates that might suggest a path forward. For instance, the Department of Astrophysics and Planetary Sciences has

developed a web-based anonymous internal reporting form for students and other department members to report adverse behavior. The form might serve as a model for Mathematics: <https://www.colorado.edu/aps/our-department/diversity-and-collegiality>.

The climate in Mathematics may also arise from the concentrated nature of the department's governance structure. The four-member executive committee presides over annual merit and salary evaluation, and at least some department faculty perceive annual merit evaluations to be unfair. While the department bylaws provide detailed criteria for evaluations, the governance/committee structure itself may concentrate decision-making power into too few hands to provide transparency sufficient to change this perception. ARPAC recommends that Mathematics review its governance structure to explore ways of broadening the decision-making base and to enhance transparency. ARPAC also recommends that Mathematics examine its merit evaluation procedures to properly credit junior faculty who have high graduate-student advising loads; Mathematics should take steps to ensure that junior faculty are not unfairly burdened with advising in relation to senior-faculty loads.

#### External Climate

As noted above, the separation of Mathematics from Applied Mathematics is still a cause of tension. The external reviewers write,

*Having a Mathematics Department and an Applied Mathematics Department in the same College is a very serious source of difficulty for the Mathematics Department and the administration, a significant source of confusion for students, and a considerable waste of resources. We believe that this distinction places CU on the wrong side of the current dynamics*

*of the subject: we currently use topology in big data, number theory in cryptography, differential geometry in chemistry and optimization, algebra in imaging, combinatorics to solve network problems, in addition to now classical applications in biology of differential equations, probability, etc. This is done by so-called pure mathematicians, including some at CU. There has been a sea change in the world of mathematics with respect to how mathematicians view the pure/applied divide: by and large, we hardly see one anymore. Applied math and pure math cannot exist without each other.*

The future relationship between Mathematics and Applied Mathematics remains an important challenge for both units and for the campus. While the external reviewers suggest that these departments' separation makes less sense today given the way the fields are developing, the reality for CU Boulder is that they are currently separate units and will likely remain so for the immediate future. Though the idea of creating a School of Mathematical Sciences incorporating Mathematics, Applied Mathematics, and a suggested statistics department has been floated, it has not gotten off the ground. Therefore, ARPAC believes that it is critical for Mathematics and Applied Mathematics to increase collaboration, taking the recent adoption of the B.A. in Statistics as a promising sign. While ARPAC understands that the missions of these units may diverge, they also intersect in significant ways. ARPAC can neither dictate nor predict what structures might arise as these fields develop, but collaboration should ultimately improve mathematics scholarship at CU Boulder, allowing students and faculty to take advantage of the strengths of each department in research and pedagogy and create a stronger whole from the separate parts. In addition to cooperating in research, faculty can and should include joint participation on search committees for future hires and collaborate on curricular development and



forming new pedagogical models. ARPAC is pleased to note that the external reviewers see hope for the future in the junior faculty's attitudes, who are not as tied up in historical disputes and who are happy to interact with their Applied Mathematics colleagues.

ARPAC concurs with the external review committee's recommendation that the memorandum of understanding between the departments be revisited and updated to clarify each department's responsibilities and teaching areas. To this end, ARPAC also concurs with the external review committee's recommendation that the college work with Mathematics and Applied Mathematics to form a "mathematical sciences" curriculum committee with equal representation from both departments and other units that rely heavily on mathematics instruction. This committee would oversee all mathematics offerings and degree programs on campus, preventing curricular duplication while also working to relieve tensions.

#### Strategic Hiring Plan

ARPAC commends Mathematics' success in attracting an active and energetic assistant professor cohort since the last review, but the department still faces pressing hiring needs. Going forward, and once climate issues are addressed and on a path to resolution, the department should revisit its strategic hiring plan. By its own account, Mathematics has too few tenured/tenure-track faculty to support its current undergraduate and graduate teaching demands. It would be helpful for Mathematics to confer about the ideal number of TTT faculty, instructors, lecturers, post-doctoral fellows, and doctoral students for adequately delivering instruction and supporting research. In particular, Mathematics should make a strong case for expanding TTT faculty lines, as long as the department also accounts for how they will maintain the balance of teaching needs to be delivered by non-TTT faculty

and TAs. Given the department's high student credit hour generation and its central role in undergraduate education, ARPAC hopes that the college dean and the provost will fully support the department.

#### Research

As discussed above, the Mathematics and Applied Mathematics division makes accurately assessing research output for either unit a complicated undertaking. The self-study states that a mathematics department without an applied mathematics component should not be compared directly in terms of grants or publications with a unit that does include applied mathematics. The self-study cites materials that give a math-specific perspective to productivity metrics and makes a persuasive case for pure mathematical research. However, even by these metrics, Mathematics appears to underperform relative to peers in the AAU public institutions. While other physical sciences units on campus rank at the top when compared with their peer groups, Mathematics appears to lag, and has not provided sufficient evidence to evaluate its relative ranking. ARPAC recommends the department find ways to make meaningful comparisons between its research productivity and that of peer programs. Mathematics should, in accordance with the internal and external reviewers' suggestion to improve communication with the college about what research looks like in the field, provide, as the external reviewers write, "the Dean's office with a full and objective list of quality indicators for the profession, perhaps extracted from the AMS or other professional societies." ARPAC would like to see metrics adopted that align with current best practices in mathematics and that account for developments in the field that transcend old disciplinary boundaries. In addition, Mathematics should work with ODA to explore creating a comparison group with a larger number of peer units by asking Academic

Analytics if it might be possible to separate the metrics for pure and applied fields at peer schools' departments that have both. The department should enforce expectations for tenured faculty to remain professionally active. ARPAC hopes that the department will find a way to use the post-tenure review process to ensure that lower-producing faculty are appropriately reviewed. The self-study in large part evades this issue by introducing metrics so vague as to potentially justify a faculty member's complete lack of research work. The unit's bylaws should spell out expectations not only for tenure, but also for post-tenure review.

The external reviewers point to a national reinvigoration of mathematical research, and CU Boulder is poised to participate in that trend. ARPAC concurs with the external reviewers that the department should do more to actively support junior faculty research. The external reviewers write,

*The research development of top-notch junior faculty requires not only excellent mentoring, but also flexibility to visit important collaborators or to attend research programs at key National Institutes, some of them semester-long and unpaid (for example, MSRI at Berkeley). In mathematics, this is a crucial aspect of supporting excellent research programs, but we learned during our visit that College rules do not allow it. On the other hand, the Associate Dean was very receptive to the idea of making exceptions in cases where (i) a faculty member's research will greatly benefit from such activities and (ii) the department can create a framework to support these activities. (For example, teaching and service can be covered in the previous two semesters, with the permission of the Dean's office, so the person can be away for a full semester with pay.) The department will benefit from investigating ways to provide active faculty, especially its junior members, this flexibility.*

The external reviewers also suggest creating additional fixed-term post-doctoral positions to address both teaching and research needs. The external reviewers offer comparisons to other mathematics departments, where the ratio of post-doctoral fellows to professors ranges from 0.4 to 2.0. Mathematics is currently below 0.2, making it an outlier nationally. ARPAC concurs that this proposal is worth exploring, provided that an effective mentorship structure precedes it. In addition, Mathematics needs to communicate the outcomes for post-doctoral fellows brought in since the last review.

ARPAC agrees with the external reviewers that Mathematics needs to move “decisively to create a vision, embrace it, and work to realize it.” A clear strategic vision will positively impact research, teaching, faculty hiring requests, and many of the department’s other pressing issues.

#### Undergraduate Program

ARPAC commends Mathematics for having improved its undergraduate mathematics pedagogy. The department continues to think creatively about curriculum, and ARPAC is confident that this already successful program will continue to improve and evolve. Despite this promising outlook, the challenge of educating so many undergraduates in a field that students often find prohibitively difficult remains steep. For example, the unit’s heavy dependence on short-term lecturers weakens its strong pedagogical model by creating inconsistencies and quality control problems. Because the department needs increasing numbers of lecturers, Mathematics should make an argument to convert lecturer positions into instructor positions to stabilize the teaching force. As mentioned above, Mathematics needs to consider the optimal balance of tenured/tenure-track faculty and non-TTT faculty positions to address teaching requirements, bearing in mind that the case for more TTT lines must include a

commitment to a larger proportion of undergraduate student credit hours being generated by TTT faculty.

ARPAC agrees with the external reviewers that Mathematics should increase its involvement in the honors program to attract the strongest undergraduate students and prepare them for graduate school or for work in mathematics-intensive fields. The unit could also create a Mathematics bachelor's/accelerated master's degree for the best students.

#### Graduate Program

While the number of undergraduate majors has increased over time, Mathematics' Ph.D. student population has seen no growth. The department currently has only one terminal master's student. The self-study demonstrates that Mathematics is actively addressing the problem of Ph.D. student retention and acknowledges that roughly half of the accepted Ph.D. students exit with only a master's degree. The self-study indicates that Mathematics is deploying available resources effectively in support of Ph.D. students, however, these efforts appear inadequate. Indeed, TA packages are not competitive, especially given Boulder's high cost of living, and the department has struggled to retain graduate students. Attrition and failure rates are particularly high for underrepresented groups, including women. As a result, the department continues to seek new approaches, including revising rules about comprehensive exam preparation. ARPAC commends Mathematics' efforts and looks forward to seeing more information on outcomes. In future reports, ARPAC requests a more finely grained analysis of the reasons for attrition accompanied by an appropriate action plan. The student questionnaire responses should also be considered, as the graduate student population appears to be aware of climate issues that are negatively impacting women and underrepresented minorities (see Climate above and Inclusive

Excellence below for more specific information). Since the internal reviewer student surveys identify communication and advising problems, ARPAC would like to see Mathematics make concrete efforts in these areas and to report on results.

The self-study indicates that Mathematics does not have enough tenured/tenure-track faculty to offer sufficient graduate-level courses to fully prepare students for exams, so the unit makes up for this lack with individual tutorials. ARPAC understands the department's concern with the turn to individual tutorials and urges Mathematics to figure out how to deliver sufficient Ph.D. coursework. If necessary, Mathematics should consider curricular reform, including timetables, preliminary exam ("pillars", as described in the department's self-study) content, and comprehensive exam content and design. Coursework should align with "pillar" and comprehensive exam content. ARPAC urges Mathematics to create a strong vision for the graduate program to justify requests for more tenure and tenure-track faculty. Such a vision, combined with improvements in climate and communication, should also help with Ph.D. recruitment.

Although the department has no plans to develop a professional master's certificate or degree (as recommended in the 2010 review), Mathematics would like to maintain their current master's program, despite low enrollments, so they may continue to have the flexibility to admit qualified and interested students for whom they cannot provide financial support. However, ARPAC questions whether this degree is worth keeping on the books in its current form, given that only one student is currently enrolled. Challenges within the Ph.D. need full department attention and attempts to revamp the M.A. program may prove to be unproductive and distracting. ARPAC

also recommends that Mathematics reinvigorate the current B.A.-M.A. track as a B.A./Accelerated M.A. degree.

According to Mathematics, both Ph.D. students lost to attrition, as well as those that go on to graduate, end up in significant numbers employed in the private sector. The American Mathematical Society's survey of graduating Ph.D. students in mathematics indicates that roughly half of Ph.D.'s are employed in business and industry, a percentage that has increased over time. Graduate student surveys in Mathematics show that students desire more mentoring towards such non-academic employment. ARPAC urges Mathematics to improve graduate student mentoring for non-academic careers as a possible (and, evidently, likely) track for future graduates.

Space  
and  
Infrastructure

The external reviewers make a strong case for increasing dedicated classroom space for mathematics instruction. The self-study suggests a relatively inexpensive way to repurpose existing classrooms. ARPAC supports renovating existing spaces to better serve the needs of active learning classes for Mathematics and other units.

The self-study also makes a reasonable plea for more office space to accommodate teaching faculty. The study outlines two workable plans (one more ambitious) to reconfigure/reclaim existing spaces. These should be given serious consideration by campus administrators, especially in light of likely faculty growth.

Inclusive Excellence

Women and underrepresented minorities in Mathematics—whether students, faculty, or staff—face a challenging climate. The internal reviewer graduate student survey indicates that a high proportion of graduate students (10 of 36 responding) do not think the department is respectful of women or tolerant of diversity. And fully one third of respondents (12 of 36) agree

that disrespectful behavior plagues the department. Given the climate issues identified by the survey, ARPAC urges Mathematics to identify and alter departmental structures that contribute to a climate that marginalizes women and people of color. Action items should clearly articulate how these changes will broaden participation by members of these typically underserved populations. Furthermore, Mathematics should collect and analyze data on the effectiveness of these changes when preparing future reports to ARPAC.

Further efforts should be made to create an inclusive environment in Mathematics and to actively recruit women and underrepresented minorities into all aspects of department development, particularly the graduate program. In addition, Mathematics should continue to seek diversity in new faculty hires, since future hiring requests will be strengthened by their attention to this issue. ARPAC also recommends that Mathematics familiarize itself with and respond to research<sup>1</sup> showing the impact of including more than one female/underrepresented minority candidate in each finalist pool.

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<sup>1</sup> Johnson, S.K., Hekman, D.R., & Chan, E.T. 2016. If There's Only One Woman in Your Candidate Pool, There's Statistically No Chance She'll Be Hired. Harvard Business Review. April 26, 2016. <https://hbr.org/2016/04/if-theres-only-one-woman-in-your-candidate-pool-theres-statistically-no-chance-shell-be-hired>



## Recommendations

The members of ARPAC address the following recommendations to the Department of Mathematics and to the offices of responsible administrators:

To the Unit:

1. Continue to work in cooperation with the college dean to implement programs and policies to address the internal climate issues identified in the self-study and by the internal and external review committees. These should include a written code of behavior. Be prepared to report and act forcefully on violations, including applying sanctions as called for by campus policies. Report to the college dean and to ARPAC on the creation and implementation of the written code of behavior.
2. Given the evidence that climate issues are influencing Mathematics' ability to retain women and underrepresented minority students, particularly in the graduate program, take concrete action to identify and disrupt departmental structures that contribute to a climate that marginalizes women and other underrepresented populations.
3. Revise bylaws to (1) change and/or clarify the department's governance structure to create process transparency related to merit evaluation and salary increases, and (2) include clear guidance on research, teaching, and graduate-student advising expectations at all levels, including post-tenure. Provide ARPAC updated bylaws.
4. The unit should review its bylaws to make sure that they comply with university and campus rules. In particular, all departments should have explicit bylaws regarding instructors and senior instructors, in keeping with the Academic Affairs Response to the Task Force on

Instructors, mentoring of faculty, and spousal hiring procedures.

5. Ensure that when junior faculty have heavy graduate student advising loads, they are appropriately credited in the merit process. Ensure that advising responsibilities of junior faculty are appropriately aligned with their research.
6. Revisit and expand upon the strategic plan, enunciating goals and needs regarding numbers and types of teaching faculty required to accommodate both current and future undergraduate and graduate teaching needs. Mathematics must come up with a well thought-out and empirically supported strategic hiring plan, reflecting their recognized pedagogical philosophy. Tenured and tenure-track faculty, instructors, post-doctoral fellows, lecturers, and graduate students all have roles to play in filling instructional needs.
7. Work with the college dean and the Office of Data Analytics (ODA) to identify appropriate ways to compare Mathematics to peer departments and to develop a set of faculty research productivity metrics. Both the internal and external reviewers include constructive ideas; Mathematics faculty may be able to generate more proposals, keeping in mind disciplinary developments and best practices.
8. Work with the college dean and the Department of Applied Mathematics to revise and update the memorandum of understanding defining the departments' respective areas of responsibility.
9. Work with the college dean, Applied Mathematics and other interested units to establish a joint mathematical sciences

curriculum and pedagogy committee to oversee all math classes and degree curricula.

10. Include as appropriate members on faculty search committees from allied departments such as physics and applied mathematics.
11. Increase Mathematics' participation in the campus honors program and add a Bachelor's/Accelerated Master's degree. A B.A./Accelerated M.A. degree may also revitalize Mathematics' M.A. program.
12. Continue to work with the college dean and external funding sources to increase support for graduate students.
13. Work with the Office of Data Analytics to track outcomes for graduate students, including keeping information on students who do not complete the Ph.D. Record how many graduates pursue academic careers and how many pursue careers in industry.
14. Expand graduate student mentoring to include information applicable to either industry or academia career paths.
15. Improve communication with graduate students about deadlines, preliminary exam content, and comprehensive exam expectations. Work to better align instruction with exam materials and goals.
16. Enhance Mathematics' strong interdisciplinary research profile based on the best practices in the field, while continuing to recognize and encourage research in pure mathematics. Engage in further collaborations with Applied Mathematics wherever possible.

17. Work with the college dean and the campus to develop active-learning classroom spaces to accommodate the pedagogical needs of Mathematics and other units.
18. Work with the college dean to identify and (as necessary) reconfigure office spaces to better accommodate current teaching faculty and graduate students, as well as to plan for possible future growth.
19. Work with the Office of the Senior Vice Provost for Planning and Budget and the quality initiative leader to develop formal mechanisms for measuring learning outcomes and student success.
20. Work with Mathematics to ensure that serious internal climate issues continue to be addressed, considering information generated by the department's external consultant as well as the internal reviewer student questionnaires and exit surveys. Set clear department improvement benchmarks and conduct annual climate reviews.
21. Ensure the appropriate implementation of post-tenure review in the Department of Mathematics. Support the chair to ensure that the post-tenure review guidelines are clear, that the process is substantive and consequential, and that appropriate sanctions are applied.
22. Work with Mathematics on updating the department's faculty hiring plan and consider well thought-out and well-supported requests for additional faculty resources.

To the Dean of the  
College of Arts and  
Sciences:

23. Modify the college policy to allow junior faculty research leaves by adjusting service and residency requirements as appropriate.
24. Work with Mathematics and the Office of Data Analytics to develop an agreed set of faculty research productivity metrics.
25. Work with Mathematics and Applied Mathematics to revisit and update the memorandum of understanding defining the two departments' responsibilities.
26. Work with Mathematics and Applied Mathematics and other units to establish a joint mathematical sciences curriculum committee.
27. Develop ways to appropriately distribute enrollment growth funding resources to units who bear the brunt of the growing undergraduate teaching loads, including Mathematics.
28. Work with Mathematics to improve support for graduate students.
29. Work with the college and Mathematics to develop active-learning classroom space to accommodate pedagogical needs of Mathematics and other units.
30. Work with Mathematics to ensure that serious internal climate issues continue to be addressed, considering information generated by the department's external consultant as well as the internal reviewer student questionnaires and exit surveys. Set clear department improvement benchmarks and conduct annual climate reviews.

To the Dean of the  
Graduate School:

To the Provost:

## Required Follow-Up

The Department of Mathematics chair shall report annually on the first of April for a period of three years following the year of the receipt of this report (i.e., April 1st of 2019, 2020, and 2021) to the deans of the College of Arts and Sciences and of the Graduate School and to the provost on the implementation of these recommendations. Likewise, the deans shall report annually on the first of May to the provost on the implementation of recommendations addressed to the college. The provost, as part of the review reforms, has agreed to respond annually to all outstanding matters under their purview arising from this review year. All official responses will be posted online.