External Review of the Mathematical Sciences Department University of Nevada, Las Vegas

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This memo is our report as the external reviewers of the Mathematical Sciences Department at the University of Nevada, Las Vegas (UNLV). This report is based on our visit to UNLV on 10-11 March 2016 and our reading of the Mathematical Sciences Department Program Review Self-Study, CVs of tenured/tenure-track faculty, and related documents. During our visit, we met with department faculty, current graduate students (without the presence of department faculty), current undergraduate students (again without the presence of department faculty), the department Chair and Associate Chair, the department Graduate Coordinator, the department Undergraduate Coordinator, the Associate Dean of the College of Sciences, advising staff in the College of Sciences, and the Vice Provost for Academic Affairs.

Before getting to the formal part of the review, we want to express our thanks to everyone involved in our visit to UNLV. We are grateful to all the people who helped arrange our visit and all the people who took time to talk with us.

Mathematics and the Top Tier Initiative

UNLV has adopted the goal of becoming a Top Tier university by 2025. Because success in obtaining external funding is a component of attaining Top Tier status, the College of Sciences will play a crucial role in the Top Tier process. Within the College of Sciences, the Mathematical Sciences Department can be a major contributor to efforts to reach the Top Tier, for the following reasons:

- Excellence in the sciences is difficult to attain without excellence in mathematics. Virtually all branches of science are now highly mathematical. The physical sciences have been seriously intertwined with mathematics for centuries. In recent years, the life sciences have been transformed by an infusion of mathematical techniques. A thriving College of Sciences requires a thriving Mathematical Sciences Department that can be an intellectual resource for other departments.
- Because mathematics is central to so many other disciplines, the Mathematical Sciences Department teaches a huge number of students who are majoring in other departments. The educational mission of the university is jeopardized if the Mathematical Sciences Department is not doing a good job of teaching students from other departments. Thus the health of the university requires a healthy Mathematical Sciences Department that does well with its teaching responsibilities.

- Top Tier status will require a sustained program of hiring outstanding faculty who can be highly productive. In the sciences, faculty often require expensive equipment in order to do their work. Thus many start-up packages for top faculty in the lab sciences at leading universities have ballooned to the near million-dollar level. Universities that cannot afford such high start-up packages face recruitment difficulties when trying to hire outstanding faculty, because top researchers in lab sciences will be at a competitive disadvantage if they do not have the appropriate equipment, facilities, and support structure. In contrast, mathematicians need very little in terms of equipment, and thus start-up costs are low. No mathematician will be at a competitive disadvantage due to equipment at UNLV. Hence an effort to recruit outstanding new faculty to the Mathematical Sciences Department may be the least expensive way for UNLV to have a high probability of making the kind of splash needed for Top Tier status. We recommend that all future hires in the Mathematical Sciences Department take place in the context of asking whether the hire helps move UNLV in the direction of Top Tier status. Because of UNLV's location in a desirable place to live, the university can expect success in hiring very high-quality mathematicians if this becomes a priority.
- The upper-division undergraduate program and the graduate program in the Mathematical Sciences Department currently have capacity to grow in size and in quality. An increase in undergraduate majors and graduate students in high-quality programs in the Mathematical Sciences Department can help contribute to the university's quest for Top Tier status, again at less infrastructure cost than would be expected in most fields of science. Further detail about these programs is contained in the next two topics discussed below.

The Graduate Program

The PhD program, established just over ten years ago, has been very successful. The Mathematical Sciences Department should be commended for the immense effort they have invested in making this program a success. The students with whom we met gave nearly uniform positive feedback. They took their teaching and research responsibilities seriously. Students are completing their PhDs in reasonable amounts of time, and are being placed in solid jobs, both academic and non-academic.

The PhD program (with roughly 25 students enrolled) is complemented by a Masters program (with roughly 30 students). Students in the Masters program are completing at good rates, and are typically placed in non-academic jobs. A smaller number continue to PhD programs, and indeed the Masters program is a good recruiting stream for the department's own PhD program.

The graduate program adds important research activity to the Mathematical Sciences Department, consistent with the UNLV's aspiration of becoming a Top Tier university. With proper oversight, the program is also a cost-effective source of high quality instruction and instructional support. This will be an essential resource for addressing student success initiatives discussed below.

In short, the PhD program is absolutely critical for research and educational missions of the department and the university. The program has significant capacity to grow, further contributing to these missions. Specifically, we make the following recommendations:

(a) The size of the PhD program should grow. An additional 10-15 students could be added with little extra infrastructure needed beyond additional GTA lines. (There is one additional consideration: space to house the additional students is a consideration, and is discussed below in the *Physical Facilities* section.) The additional GTA lines are also relevant for the recommended proposal discussed below in the *Lower-Division Courses* section.

(b) There is good evidence that the department is screening for potential teaching ability when recruiting PhD students. (For example, all of the international students we met had good English and interpersonal skills.) Given the critical role that the graduate program can play in student success initiatives, this should continue to be a point of emphasis. In addition, new GTAs should be required to complete a serious teacher-training workshop. Follow-up observations should be conducted, and feedback should be given to improve the quality of instruction offered by GTAs. Recruiting such high quality students is a constant challenge, and the Graduate Coordinator should be supported by the higher administration in these efforts.

The Undergraduate Program

We met with a good group of undergraduate students who are currently majoring in the Mathematical Sciences Department. No one was was present during these discussions except the students and the two external reviewers. We promised the students that none of them would be identified by name, and we told them that we wanted to hear what was good about their program and what was not so good.

Overall, we found the undergraduates to be remarkably happy and satisfied with the quality of their experience as majors in the Mathematical Sciences Department. The students reported good interactions with the departmental faculty, good access to faculty when they needed help, and generally quite good teaching. A very positive indicator is that some of these students are considering staying on at UNLV as graduate students in the Mathematical Sciences Department after they receive their undergraduate degrees. The suggestions we give below for improvements in the bachelors degree programs should be viewed in the context of a program that is doing well.

The only serious complaint concerning the curriculum that we heard from the students concerned Math 457, which is a required course for all the department's undergraduate degrees. Math 457 is the first course in real analysis. Some of the students who otherwise did well in their classes failed Math 457 and had to retake it. Students who had not yet taken Math 457 have heard about its reputation and were apprehensive about the upcoming experience.

For students, the hard part of the real analysis course is dealing with proofs. Doing proofs is quite different than the kind of mainly algorithmic mathematics that fills up most calculus courses, first courses in linear algebra, and first courses in differential equations. Thus the real analysis course has long been recognized as the hardest required course for students in math majors throughout the country.

As proofs were removed from many American high school geometry courses, many American universities noticed that their math majors were struggling with the required

real analysis course. Most American universities dealt with this situation by adding a new course on how to do proofs, making this course a prerequisite for the required real analysis course (and often also for the abstract algebra course). UNLV is among the minority of American universities that has not followed this path. The current situation at UNLV for real analysis is not working, as was acknowledged to us by some faculty when we mentioned this problem.

The topics covered in Math 457 are quite standard for a first course in real analysis. The textbook used for the course (at least for this year) is a good choice. Math 457 does not need to be redesigned. But the students coming into the course are unprepared because they have not had sufficient experience with proofs.

As the solution to this problem, we strongly recommend that UNLV follow the national trend and establish a new course on proofs that will be a prerequisite (with a grade of C or higher) for Math 457. The University of Nevada at Reno already has such a course. We understand that UNLV uses the same course numbering and course approvals, and thus the bureaucracy for offering this course at UNLV should be low. Here is the catalog description of this course at the University of Nevada at Reno:

> **Math 301,** *Introduction to Proofs; Logic, Sets and Functions*. Logic; mathematical induction; elementary set theory; functions; properties of integers and real numbers. Heavy stress on mathematical proofs.

The mathematical content of the proof course varies from university to university. The important thing is that the students should get lots of practice with the kind of proofs that they will encounter in real analysis and abstract algebra.

A few people mentioned to us that students currently get some introduction to proofs in Math 251 (Discrete Mathematics). We want to emphasize that we believe that Math 251 will not adequately serve the purpose of preparing students for the proofs in Math 457. We have two reasons for this belief: First, Math 251 has not worked to prepare students in the past for Math 457. Second, only a small minority of the students who enroll in Math 251 are majors in the Mathematical Sciences Department. It is not possible to present proofs to such an audience in the depth needed for math majors. Again, we strongly recommend that UNLV start offering Math 301 and making it a prerequisite for Math 457. We believe that the faculty who teach Math 457 will be much happier with students who are appropriately prepared for the course.

Again within the context of students who are happy with the undergraduate program, the only other complaint that we heard from students in addition to Math 457 concerned the selection of upper-division courses. Some upper-division Math courses are offered only every other year at UNLV. The selection of upper-division Math courses in any semester is not as large as the students would like. These problems stem from the relatively small number of undergraduate majors in the Mathematical Sciences Department.

For the last three years of data as given in the department's self-study, the department awarded an average of 18 bachelors degrees per year over those three years. As noted in the self-study, the number of undergraduate majors in the Mathematical Sciences Department is about half the nationwide average for math departments (as a percentage

of the total number of students in the university). About half the students entering UNLV place into remedial math, but this cannot explain the small number of math majors because other public universities of comparable size also have about half their students placing into remedial math but attract many more math majors.

Whatever the reason for the current number of math majors at half the national level, we recommend that the Mathematical Sciences Department devote considerable energy to attracting more undergraduate math majors, with the goal of at least doubling the number of majors (and thus getting to the national average). More undergraduate math majors would solve a lot of problems and lead to a better degree: More upper-division courses could be offered every year, instead of every other year, thus reducing the time-to-degree for some students. Upper-division courses would have a healthier enrollment—there is much more class interaction with a class of twenty students than with a class of ten students (and the cost to the university is about the same). The variety of courses could be expanded. With more majors, students would have more opportunity to learn from each other.

To increase the number of undergraduate math majors, the department may need to have an increased focus on recruiting and advising. For example, it should become a standard practice that once a semester, every instructor in every calculus class should take ten minutes to talk about the wonderful things that one can do with a mathematics degree. If only a minuscule percentage of computer science and engineering majors switch to math, then the problems of having too few math majors will be solved.

Lower-Division Classes

Increasing student success in lower-division math courses is critical to the educational mission of the university. Students who successfully complete these courses early in their undergraduate careers are far more likely to complete their degrees programs (and to do so in a timely manner). Relatively modest investments in these courses can lead to significant gains in key measures like graduation rates and time-to-completion statistics.

Addressing success rates in lower division math classes requires the coordination and support of many units on campus, beginning with the Mathematical Sciences Department, but also including the Math Learning Center, other academic units whose students the department serves, the higher administration, and the advising infrastructure on campus. There are many competing pressures. Everyone would naturally like to see higher admission and placement standards, but this is not a realistic possibility in the short-term (or even middle-term). Placing students in a long sequence of developmental math classes often yields very few students who successfully complete the sequence, placing pressure to *lower* placement standards and reduce the number of prerequisites for lower-division courses. On the other hand, the mathematical integrity of courses offered at UNLV cannot be compromised, particularly for students pursuing STEM careers: passing unprepared students in one math class will not serve them well when they take future quantitatively intensive courses.

These competing pressures have led to friction between the Mathematical Sciences Department and other stakeholders mentioned above. This situation is not sustainable and must be addressed immediately. The consequences of inaction are significant, both for the students that the department serves and for the long-term stability of the

department itself. To its credit, over the years, the department has considered and, in many cases implemented, a number of innovative ideas, like early interventions for at-risk students and increased emphasis on student engagement (through computer-based homework tools that provide instant feedback). However, more needs to be done.

The courses offered by the Math Learning Center, 095 and 096, are prerequisites for terminal quantitative literacy classes, such as Math 120 Fundamentals of College Mathematics, and for STEM-preparation courses such as Math 128 Precalculus and Trigonometry (and its two semester version Math 126-127). Because courses such as Math 120 and Math 128 (as well as the teacher-preparation courses Math 122-123) serve different populations of students, it may make sense to rethink the pathways to these courses, in collaboration with the Math Learning Center. For example, perhaps a carefully designed one-semester 090-level course may be adequate preparation for Math 120.

From the point of view of shortening time to graduation, the one-semester Math 128 is far preferable to the two semester Math 126-127 sequence. We recommend that the department, in collaboration with the central advising unit, consistently recommend Math 128 to STEM majors, rather than Math 126-127. (We recognize that for a certain population of students, for example those with significant family or work commitments, Math 128 may not be possible.) We also recommend re-evaluating the content of Math 126-128 with a specific eye toward exactly what is required for calculus. For example, the three-credit course Math 127 Trigonometry appears to contain far more trigonometry content than is needed for success in calculus.

Finally, we recommend that the Mathematical Sciences Department undertake a concerted effort to increase student success in its lower-division offerings. Specifically:

(a) The Chair, Associate Chair, and Undergraduate Coordinator, in consultation with the full faculty, should codify a proposal to address student success through launching a pilot program in one (or perhaps a handful of) lower-division courses deemed to have the greatest impact.

(b) The proposal should include specific details of mechanisms to support students. These may include additional required weekly sessions led by graduate student TAs that address just-in-time remediation for upcoming lectures; administer weekly quizzes and provide immediate feedback on them; and offer additional problem-solving sessions integrated with the curriculum. The department should also consider systematic development of teaching skills of graduate student instructors (for example through weekly meetings of GTAs involved in the pilot).

(c) The proposal should include a specific timeline for implementation, as well as details for assessing the effectiveness of new mechanisms to support student success. Specific milestones (to be reviewed after two and four years of implementation, for example) should be specified.

(d) The proposed activities and assessment should be carefully coordinated across all sections through regular meetings with instructors.

(e) The final proposal should include feedback from all relevant stakeholders, especially the Math Learning Center (whose courses provide a significant stream of students into classes such as Math 128), the College of Sciences and the College of

Engineering, and the Provost's Office. The university's advising staff should be engaged to determine the logistics required for a smooth implementation.

(f) The proposal should include a detailed justification of the resources required to implement the proposed activities successfully. Reliance on part-time instructors is unlikely to lead to successful implementation. At least one dedicated FIR coordinating the new activities will be required, as will additional teaching personnel in the form of additional graduate TA lines. (The latter are consistent with expanding the graduate program, as discussed above.) The proposal should make a clear case for the impact of the requested resources.

If the proposed activities are successfully implemented, then the department should move to institutionalize the pilot program, and consider expanding it to other key offerings.

Faculty Development and Teaching Loads

As the university moves toward Top Tier status, the research and scholarly expectations of the faculty will increase. We are happy to note that about two-thirds of the tenured/tenure-track faculty in the Mathematical Sciences Department currently have active research publication records. We encourage the continued development of a departmental culture that supports active research by the faculty.

The Mathematical Sciences Department currently has about thirty tenured/tenure-track faculty, but only one assistant professor. Most research-active mathematics departments in the United States have a higher percentage of assistant professors than does UNLV. Assistant professors make important contributions to the research atmosphere of a mathematics department by bringing exciting new research directions from their doctoral and post-doctoral institutions. Currently the Mathematical Sciences Department at UNLV is too top-heavy at the full professor and associate professor level. We recommend an increase in the number of assistant professors in the department. The department should have extremely high standards in hiring new faculty; we believe that it is realistic for UNLV to attract outstanding mathematicians to its faculty.

Teaching load will be an issue in attracting the best job candidates. Top researchers will want working conditions that allow them to excel. A reduced teaching load (perhaps two courses one semester and one course the other semester) for at least the first few years can be an attractive recruiting tool. Prospective faculty will also want to know about their long-term teaching load. To be competitive and to give faculty adequate time to produce high-quality research, we recommend that research-active faculty should expect a teaching load of no more than two courses per semester. Faculty who have shifted away from research-intensive activities might expect to make additional contributions to the teaching mission of the department, perhaps by teaching three courses per semester.

The Physical Facilities

The department occupies several adjacent small buildings in the Central Desert Complex (CDC). These buildings provide tight quarters for faculty and students, and would likely be inadequate to house additional graduate students if the graduate program were to grow. Additional faculty are housed at the Science and Engineering Building (SEB).

This fractured arrangement directly affects the cohesiveness of the faculty and the quality of the educational experience for the students they serve. For example, several faculty members indicated that the building arrangement led them to spend most of their time working from home. Students do not have adequate places to congregate for activities such as informal review sessions or well-attended office hours in the CDC.

Centrally locating all Mathematical Sciences Department faculty in the same building (allowing for modest room to grow the graduate program) will improve the student experience in their mathematics classes primarily though increased opportunities for student-faculty and peer interactions. It will also improve the morale among faculty, staff, and students currently scattered in the CDC and SEB.

It is not reasonable to expect a new building to be constructed for the purpose of housing the Mathematical Sciences Department. However, when new space does come online (like the new building for the College of Health Administration), we recommend that the entire Mathematical Sciences Department be moved to a single location vacated by the occupants of the new building.

The Chair

During our visit to UNLV, we picked up indications of serious past tension between the Mathematical Sciences Department and the central administration of the university. We have no desire to delve into that history. Instead, we encourage everyone to start over with new attitudes of working together to produce a new situation that benefits everyone, especially students.

This is an especially good time for relations between the department and the central administration to start anew because the department has an terrific new Chair, Zhijian Wu. Professor Wu is an excellent leader who can raise the profile of the department nationally while making changes that lead to better outcomes for UNLV's students. We strongly recommend that the central administration and the department's faculty provide full support to Professor Wu as he helps lead the department to address critical problems and opportunities.

Summary

The Mathematical Sciences Department is well positioned to advance several of UNLV's most important priorities. By expanding its undergraduate and graduate programs and adding highly productive new faculty, the department can be instrumental in propelling the university to Top Tier status. By focussing on student success in its gateway offerings, the department can help improve graduation rates and time-to-completion statistics. The research and educational activities of the Mathematical Sciences Department, and the resources needed for their support, are closely intertwined. These activities offer the university a high rate of return on any investment made in them.

To be successful in carrying out the recommendations above, the Mathematical Sciences Department must work immediately and collaboratively with other stakeholders on campus. This will be particularly critical for addressing student success in its lower-divisional courses. Sustained progress will only be achieved by a faculty deeply dedicated to advancing UNLV's research and educational missions, and an administration that recognizes and rewards such dedication.