

Multiple Approaches to Improving Quantitative Skills at James Madison University

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Improving the quantitative skills of all students and enhancing the development of quantitative skills within major programs require looking and working well beyond the boundaries of individual departments. At James Madison University (JMU), the Department of Mathematics and Statistics has been reaching out and connecting with general education and through departments and programs across campus with a comprehensive approach. Careful thought and planning is required to achieve a balanced and comprehensive approach to improving quantitative skills and reasoning in response to multiple demands. These sometimes competing demands include the need to establish effective and measurable liberal education goals for all students, the need for specific skills for students in traditionally quantitatively-oriented disciplines, the evolving need for quantitative skills in areas not previously thought of as “mathematical,” and very special needs for teacher preparation. One guiding principle is to encourage more students to learn more mathematics and statistics and to provide more opportunities for them to apply this knowledge within major programs.

Freshman Advising

All entering freshmen at JMU take an algebra-based placement exam. We have carefully examined the mathematics placement scores and the eventual performance of students in basic mathematics and statistics courses, using the information to develop a matrix for freshmen advisors in collaboration with the general education program. Our intent is to improve placement

and, therefore, success in mathematics and statistics courses. Standards are not changed, but we try to avoid advising students into courses where they have little chance of succeeding. We also try to avoid “math-phobic” advising—the kind of advice that would suggest a student go take that one required math course and get it over with—or advising that suggests that freshmen in certain majors must take a certain set of courses immediately, even if they are not fully prepared.

We have extended the attention to advising to combine mathematics placement scores in other areas. For example, mathematics placement and math SAT scores are reliable predictors of passing general chemistry. Student effort is obviously an important factor, but below certain placement scores the probability of passing is essentially zero due to the extensive use of algebraic manipulations. As a result, some entering biology majors may be advised to delay general chemistry until they have completed a particular mathematics course. Similarly, we have found that students who might have mathematics placement scores adequate to enroll in statistics do not perform well if they have lower SAT verbal scores. However, after taking a course in writing, their chances of succeeding in statistics improve because of increased proficiency in working through written problems.

Support

Recognizing that nearly all students can run into a mental block in a mathematics course and may benefit from additional support, we have developed the

Science and Mathematics Learning Center to provide professional assistance in working through problems in basic mathematics, statistics, and science courses. The center has two full-time professional faculty members who, assisted by trained students, work with approximately 10,000 student visitors each year. Assessment of grades for students using the center indicates improved performance. Similarly, we provide supplemental instruction by student mentors for a number of key classes in which students often struggle. This too produces positive results.

Paying careful attention to hiring, staffing, and delivery of courses is essential. We search for faculty who are balanced teachers and scholars—and who are genuinely interested in working with undergraduate students. Departments match faculty strength and pedagogical approaches to the levels of the course. For example, peer mentoring has produced benefits in general chemistry and in entry-level computer information system courses, both of which emphasize problem solving.

Assessment

All entering students take assessment exams during orientation for the fall semester. In the spring semester of the sophomore year, the students are reexamined during a day devoted to assessment university-wide. Thus, we can examine their performance and compare it with the courses they have taken to satisfy general education requirements. The exams were developed by our Center for Assessment and Research Studies in conjunction with faculty mem-

bers who have written questions related to the learning objectives for general education. One of these exams covers quantitative literacy. In addition to the testing of all students, the Department of Mathematics and Statistics is in the process of assessing outcomes across a series of mathematics courses as part of a project with the Mathematical Association of America.

Curricular Changes

Within the Department of Mathematics and Statistics, there have been many curricular changes designed to improve the

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preparation of students. For example, a new calculus sequence was developed for students who might have gaps in their preparation and not be fully prepared for science-oriented Calculus I. The two-semester course combines calculus and precalculus, is very rigorous, and fully prepares students to be successful in Calculus II. This route has become very popular for many majors in chemistry and biology. Previously, many of these students would have enrolled in a softer “terminal” calculus course, making it difficult for them to

continue on to the advanced mathematics courses that are becoming increasingly important to these disciplines.

A course in discrete mathematics was expanded into a sequence in very close collaboration with the computer science program. A course in quantitative geology has been offered as a result of collaborations of geologists and mathematicians. Working with the College of Education, an elementary and middle school teacher preparation program has been developed, which includes three core courses for all teachers followed by four upper-division courses for middle school mathematics teachers and elementary school mathematics specialists. A computational science minor has been implemented jointly with physics and a course in “Mathematical Models in Biology” has been developed and co-taught. Each of these areas grew from faculty collaborations, and new faculty have been hired to support the developing connections across disciplines. We also are seeing evidence of additional quantitative and analysis courses springing up within the disciplines.

Minors and Majors

Students can benefit greatly from a minor. We offer minors in mathematics and in statistics, and both are increasingly popular. The mathematics minor is often taken by students in the natural sciences and in business. The statistics minor is frequently chosen by students in the health professions, psychology, and sociology. For the students in the biomathematics course mentioned above, the mathematics majors

indicated that they would take more biology and the biology students that they would take more mathematics, with some deciding to add a minor. These impacts suggest that infusing more mathematics into biology (and other courses) may be successful.

As students become more aware of the practical benefits of additional mathematics and the interesting and rewarding new opportunities that result, faculty in mathematics and statistics are collaborating with those in science, business, and computer science on plans to make it more convenient for students to pursue a double major while still meeting the core demands of the individual disciplines. A new statistics major promises to be a popular choice as a second major for students in several other disciplines.

Interdisciplinarity

Many fields have become more quantitative over time, especially biology, chemistry, and finance. This is also true of professional programs and a wide range of disciplines. But what quantitative applications and approaches are being used? Have they changed over time? What might be the best preparation for students?

These questions are not simple ones and require connections and conversations among mathematicians, statisticians, and faculty working in other programs. Our experience suggests that collaborative course development and research help faculty appreciate quantitative applications in other fields, which is especially true in interdisciplinary research questions. But that is only

one piece of the answer to these questions. Making substantial progress in improving the quantitative skills and reasoning of students requires careful attention to the development of a student in a very intentional way—something most majors rarely consider. For example, if we are interested in having students engage in a capstone experience that involves research, possibly as part of an interdisciplinary team, we should align a curriculum intentionally to prepare students for such an experience. Sometimes majors have been constructed and offered as collections of courses, with coherence often lacking. However, if we are to develop quantitative reasoning in students, it cannot be accomplished solely by requiring certain courses in mathematics or statistics; it will require attention to enhancing quantitative skills within a major program.

Undergraduate research experiences have brought faculty together in new ways and have developed further connections between disciplines. For example, our Materials Science Research Experiences for Undergraduates program, funded by the National Science Foundation, includes faculty mentors from several departments, including mathematicians, and mathematics majors have participated in research programs in other disciplines. Statisticians frequently work with students from a range of disciplines as they engage in senior projects or other research experiences. More recently, work in visualization emanating from the Center for Computational Mathematics and Modeling by applied mathematicians and physicists is sparking interest from faculty from a wide range of

areas, including economics, art, computer science, and geology, among others.

Conclusion

Rapid developments in many fields, emerging disciplines, blurring boundaries, and the need for enhanced quantitative skills challenge us all to provide improved quantitative preparation for our students.

Responding effectively requires careful reexamination and coordinated design of curricula, which may in some cases mean changes in cognate requirements, revisions to existing courses, and more attention to building quantitative skills within major programs. We suggest that, in order to be successful, it will be necessary to recognize student backgrounds and support developmental progress of students in an organized way, to reach out from mathematics to disciplines to understand and serve their needs, to build connections with disciplines, to use multiple approaches and curricula designed for different purposes, and to assess outcomes related to learning goals.

Clearly we are calling for a comprehensive approach and fully recognize that many steps are required over a period of years to produce the kind of transformation required. What we envision is not the isolated island of mathematics that, unfortunately, has been in the minds of many faculty (or even within departments of mathematics), but rather departments at the center of a university with helpful hands interdigitating across a campus with vibrancy and excitement in pursuing quantitative solutions and applications in a wide range of settings. ■