Unity in Multiplicity: Lessons from the Alhambra

By Randy K. Schwartz

Excellence in the Academy Awards
Democracy in Higher Education

A copy of "Talking About Race" landed on my doorstep in July 2000, three days after I returned from a mathematics conference in Granada, Spain. It was a special issue of the *New York Times Magazine*, capping that newspaper's yearlong probe of race relations in America.

In one column, journalist Rubén Martínez wrote:

> All across the country, people of different races, ethnicities and nationalities are being thrown together—and torn apart—by the churning forces of first the postindustrial and now the information economy.… It is a terrifying experience, this coming together, one for which we have as yet only the most awkward vocabulary. One for which new languages are being written.[1]

The mixing of different peoples and cultures can be "terrifying," as Martínez put it. But there is another way to look at the issue. All too often, discussion and debate about multiculturalism has focused one-sidedly on the "terrifying" contours of the problem.

In fact, phrases such as "the *problem* of racial diversity" and "the *problem* of affirmative action" fairly trip off the tongue. By contrast, a phrase such as "the *treasure* of racial diversity" or "the *opportunity* for affirmative action" strike most people as awkward.

Perhaps nowhere on earth has this denial of the historical legacy of multicultural richness reached such ironic proportions as in Spain, parts of which were ruled for eight centuries by highly cultured Moorish élites of Arab, Berber and Jewish extraction.

Of late, southern Spain has

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been torn by a wave of violent attacks on recent Moroccan immigrants. In February 2000, in a three-day pogrom that came to be known as "la guerra" , bands of armed Spanish men yelling "Out with the Moors!" went on a rampage, chasing North Africans through the streets of El Ejido and other towns, firebombing immigrant shanties and destroying several teahouses and mosques.

"They came with sticks and bars," one immigrant described the attacks. "They always treat us like dirt," he said, "but this time they behaved like Nazis. Many people had to run for their lives."[2]

Two months later, the mobs torched a foreign-language newspaper kiosk and a telephone center used by immigrants to call relatives in their home countries.[3] No doubt Martínez had racial strife such as this in mind in writing his column.

In the face of these attacks in southern Spain, the Alhambra 2000 conference in Granada pointedly brought together 300 educators from Arab and European nations. Alhambra 2000, or the European-Arabic Congress of Mathematics, was a satellite event of the third quadrennial European Congress of Mathematics, a larger gathering in Barcelona last summer.

The core of the conference was a set of presentations exploring the contributions of Arab cultures to current knowledge of mathematics, an idea conceived by Finnish professor Osmo Pekonen to coincide with the celebration of 2000 as the International Year of Mathematics.

In digging up the hidden history of Arab discoveries in science—and in the living example it provided by unifying scholars from traditions and homelands that have sometimes been mutually hostile—Alhambra 2000 made a convincing case that the most successful undertakings, not only historically but in modern times as well, are those that tap into the cultural, linguistic and ethnic diversity of the planet.

This lesson has important implications for higher education in the new millennium in cosmopolitan countries like the United States.

It is no small task to bring educators from many nations to a forum where meaningful exchange can take place. The participants in Granada represented most countries of Europe and northern Africa, and other continents as well.

Delegates from impoverished regions of Asia, Africa, and Latin America were offered financial assistance by the Spanish government through its Institute for Ibero-American Cooperation and Institute for Cooperation with the

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Arab World, Mediterranean, and Developing Countries.

What a refreshing contrast this represents after the years of the Francisco Franco dictatorship (1939-75), when mathematics and other sciences in Spain were cut off from the rest of the world. The congresses in Granada and Barcelona were the first important international math conferences held in the country since that period came to an end.

The decades of fascism had stunted Spanish intellectual and academic life in a way that is still felt today. Under General Franco, research funding and other academic privileges tended to flow toward those with the most powerful connections to his government.

The regime went so far as to dispatch secret police to key schools and other institutions to operate as spies. The university system came to be marked by political maneuvering, factionalism, and the lowering of standards, reminiscent of what Lobachevsky and other mathematicians faced in the previous century in Russia under Czar Alexander I.[4]

Franco's nationalism had become so extreme that he viewed the Catalan nationality—a major cultural group centered in Barcelona and northeastern Spain—as a threat to his rule and did everything he could to wipe out their language and culture. This helps explain, for example, why Catalan mathematician Ferran Sunyer i Balaguer (1912-67), considered one of the world's leading experts in classical analysis, scarcely achieved recognition in his own country.

Today, advocates of innovation in Spanish schools and universities confront a Ministry of Education and Culture that still favors tradition and centralization. However, the innovators have vowed to launch the kind of curricular reforms that in other countries have helped to more closely link educational activities with national and student needs.[5]

Catalunya is now an autonomous region within Spain, and the Catalan Mathematical Society (SCM), principal organizer of the parent congress in Barcelona, is a leading center of intellectual activity.

SCM President Sebastià Xambó has commented that in the quarter-century since Franco's death, the mathematical research in Spain has risen from next to nothing to being a player on the world stage. In 1998, the Spanish Royal Mathematical Society (RSME) joined 39 sister organizations in the European Mathematical Society (EMS). Convening these congresses in Spain, Xambó noted, "gives us a good opportunity to symbolize this stage in a public event."[6]

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English was the official language of Alhambra 2000, a reflection of its increasing dominance—for good or ill—in international scientific discourse. I was certainly impressed that the vast majority of speakers—most of them native speakers of Spanish, French or Arabic—were comfortable presenting in English.

The exceptions, too, were handled in interesting ways; for instance, a number of presenters spoke in one language while projecting slides written in another. When Manuel Ojeda and his colleagues used PowerPoint to present their joint work on computerized automatic theorem-proving, they were using a Windows operating system whose user interface was in Spanish—an important new tool in a world in which computer use is rising rapidly among Spanish speakers.

Reportedly, the Internet community alone now includes 9 million people in Spain and 13.2 million in Latin America, the latter figure up from 8.4 million just one year earlier.[7]

The importance of multilingual understanding among scientists was underlined by an historical example cited by Finnish professor Taneli Kukkonen in his talk on the astronomy of Abu al-Walid Ibn Rushd (Averroës), the great Arab scientist-philosopher of 12th-century Córdoba, Spain.

Ibn Rushd championed Aristotle's sphere-based model of the heavens against a clever but equally Earth-centered model that Ptolemy devised from cyclic and epicyclic orbits. Aristotle had spoken of "counteracting spheres," a phrase that was translated from Greek into Arabic as *lawlabiyah*. Ibn Rushd construed the latter as "spiral"—a misinterpretation that led him down a very blind alley, for gravitational orbits are certainly not spirals!

The opportunity for understanding to be forged from many languages and many cultures has special poignancy in Granada. Scholars generally agree that the reason Moorish Spain rose in the Middle Ages to become the most advanced civilization in Europe was that—in stark contrast to the sieges, expulsions, and inquisitions that would later "ethnically cleanse" the peninsula—the Moors presided over a multicultural society.

Extant works of science and philosophy by Spaniards such as Ibn Rushd, a Muslim, and Ibn Maymun (Maimonides), a Jew, bear testimony to the intellectual ferment of a land where Arabs, Berbers, Jews and Christians coexisted.[8] The intermixture of ideas and techniques also shaped Iberian literature, agriculture, and art: Silk, for example, made by Arab craftsmen

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using Asian methods, became Granada's leading export.[9]

The Alhambra itself, Granada's fortified palace complex and the last Moorish bastion to fall to the Christian reconquest in 1492, would perhaps not strike most people as a prime travel spot for a mathematician. In fact, however, the bold mosaics, graceful arabesques, and ingenious garden landscapes are of great mathematical interest due to their intricate geometric designs. This geometry is also a commentary on the broad sweep of the Moorish intellect and its spirit of embracing all.

The abstract focus of Islamic art and architecture is rooted in the reluctance of early Muslim artists to depict humans or animals, which was believed to usurp the creative activity of Allah.[10] That a single word, *al-hindasah*, is used in Arabic to denote "geometry," "architecture" and "engineering" is a legacy of the importance attached to thoughtful design in the Medieval Arab world.

We were able to examine colorful examples of such designs on a mathematical tour of the Alhambra. The conference organizers had armed each of us with a twofold pocket mirror useful in viewing intricate symmetries of various kinds: reflections, rotations, and regular repetitions—known in mathematics as "translations."

Conference speaker Rafael Pérez-Gómez of the applied mathematics department at the University of Granada has studied these symmetries in depth. His work shows that in the construction of the Alcázar, the splendid 14th-century Nasrid palace of the Alhambra, the fascination with abstract geometric ornamentation reached such a level among artisans and geometers that they discovered and utilized every one of the 17 possible symmetrical ways to cover a wall with tiles.

This was an intellectual feat without precedent. At no other cultural site in the world are more than a handful of these "planar crystallographic groups" found; in all of the ruins of ancient Egypt, for example, only 12 of the 17 were employed.[11]

Medieval Islamic designers were not in a position to systematically work out the mathematics of symmetries, such as figuring out why there are exactly 17 kinds—this became possible only with advances in the study of geometry in 19th-century Europe. Instead, what was pushing the Moors' investigation of symmetry to new heights was their keenness—almost obsessive in its fervor—to discover and reveal every intricacy of divine creation.

Muslim Spain was one of the most cosmopolitan and multicultural societies in human history.

Using repeated and interlocked ornamental figures was also a way to broadcast the Islamic doctrine of *al-tawhid* (pronounced "at-toe-HEED"), variously translated as "unification" or "unity in multiplicity." *Al-tawhid* views all of the multifarious phenomena of nature and society as stamped by a single spirit that permeates everything, so that the boundless multiplicity of the universe is an expression of a more underlying unity.

A helpful analogy often cited by Muslims is the way in which all lustrous objects on Earth reflect the qualities of their common Sun, notably light and heat. Because of this unity or oneness, the ignorance of any one thing in the universe is seen as an ignorance not simply of that thing alone, but of what might be an important key to understanding the whole cosmic text in which the unified workings of nature are revealed.[12]

"Every pomegranate has one seed which has come from heaven" was a saying popular in Andalusia and especially in Granada, itself a namesake of the fruit. Metaphorically as well as literally, the Moors took care not to drop or lose pomegranate seeds, knowing that any one of them might come from Paradise.

It isn't hard to see how such beliefs can encourage the embrace of all knowledge and all people. This was exactly what was taking root in Muslim Spain, one of the most cosmopolitan and multicultural societies in human history. The proverb of the pomegranate is an apt metaphor for the attitude that we might bring today to the question of diversity in education and the society.

As I interpret *al-tawhid* and its relevance to our situation, I see two complementary facts. To the extent that a multicultural society such as ours tries to blot out any people or culture, the various groups will be divided against each other in hostile camps: Thus, there can be no unity without multiplicity—tolerance.

When it is isolated from others, the cultural vigor, survival, and flourishing of any one group is threatened, for no island can command the knowledge and resources offered by the world entire: thus, there can be no multiplicity—diversity—without unity. Unity and multiplicity are themselves indivisible phenomena.

Mathematics and science do not magically leap cultural and political borders by themselves. Today, as in the past, the flow of knowledge requires broad channels of social exchange.

Historically, east/west contact bore the most fruit wherever Arabs and Europeans lived or

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worked together. As conference originator Osmo Pekonen reminded us, it was at Arab-influenced monasteries in Ripoll, Spain and Bobbio, Italy that a young monk named Gerbert d'Aurillac first learned Hindu-Arabic numerals and the simplified arithmetic they made possible.

Much later, in 999, Gerbert would be crowned Pope Sylvester II. But imagine his youthful courage in defying official church opposition to even studying the Arab techniques!

Continued hostility to all Muslim ideas was one of the reasons the Hindu-Arabic methods introduced by Gerbert did not take root in Christian Europe until more than two centuries later, with the work of Leonardo Fibonacci of Pisa, Italy.

Conference speaker André Allard read us a passage from a letter by the young Fibonacci in which he discusses staying some days at his dad's trading post in Bejaia, on the coast of Algeria, in order to "study the abacus," a code word for Hindu-Arabic arithmetic. The father had insisted the son learn Arab methods because they made commercial calculations so much easier—a not insignificant factor in the growth of Italian economic supremacy in the Mediterranean.

In modern times, the rise of mathematics and science in Europe and the United States was accompanied by an increasing blindness or willful ignorance of the contributions of non-European cultures. Consider the following statements, all by highly respected mathematicians and historians of science:

"The history of mathematics cannot with certainty be traced back to any school or period before that of the Ionian Greeks."[13]

"[Mathematics] finally secured a new grip on life in the highly congenial soil of Greece….With the decline of Greek civilization the plant remained dormant for a thousand years…when the plant was transported to Europe proper and once more imbedded in fertile soil."[14]

"Arab science only reproduced the teachings received from Greek science."[15]

It is time to reject these Eurocentric views of history. As the presenters at Alhambra 2000 documented, in mathematics alone, much of arithmetic, algebra, trigonometry, combinatorics, and the analysis of functions was first pioneered by scholars in the Arab world.

The list of Medieval and Renaissance Europeans directly influenced by Arab mathematical advances includes not only the cele-

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brated examples of Gerbert and Fibonacci, but such figures as Hermann of Reichenau, Adélard of Bath, Gherard of Cremona, John of Sacrobosco, as well as Llull, Regiomontanus, Raimondi, Clavius, Stevin, Kepler, Viète, Fermat, and Wallis.

The extent of this influence prompted George Saliba, speaking on the diffusion of mathematical planetary theories, to ask rhetorically, "Whose science is it—Arab or European?" He argued that old labels such as "Islamic science" are no longer tenable, because they attempt to wall off cultures more than the cultures are walled off in the real world.

Today, with a satellite-based "information superhighway" speeding the cross-border flow of data, it has become fashionable to declare that barriers of distance and time, and differences of politics and culture, no longer matter at all. Nevertheless, the biggest breakthroughs in education and research still hinge on humans working together "on the ground."

Conference speaker Michel Balinski, for example, a math professor in France, collaborated closely with colleagues from the Turkish Ministry of Education to invent a computer algorithm that can more fairly and efficiently assign students to universities.

Such assignments in Turkey have long been determined not by the universities and students but by the government, based on competitive exam scores and areas of specialization. Historically, the process was done by hand, a clerical nightmare involving over a million students and a hundred schools.

Balinski's breakthrough, which applies graph theory to any "two-sided market of preferences," has applications not only for school admissions but hospital internships and other types of admissions programs as well.

The need—and opportunity—for a more multicultural approach in U.S. education has become more evident. The diversity of student, resident, and worker populations in this country has increased markedly and will continue to accelerate for some time.

Recent figures from the U.S. Census Bureau indicate that some 26.4 million Americans today, or about 9.7 percent of the population, were born in other countries. Never before have we had so many foreign-born residents, and the vast majority of these—84 percent—are from non-European nations.

The Bureau of Labor Statistics has reported a jump to 15.7 million immigrant workers, or 12 percent of the U.S. workforce. The Educational Testing Service projects that

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by 2015, the proportion of nonwhite students at U.S. college campuses will increase to about 38 percent, accounting for some 80 percent of growth in the student population.

The rapidly changing complexion of the U.S. workforce prompted General Motors, the largest corporation in the world, in July 2000 to take the highly unusual step of filing an amicus brief in support of affirmative action admissions to the University of Michigan. GM filed the brief in a pair of lawsuits scheduled for trial in early 2001, in which three white students denied entry to UM have challenged the university's admissions policy, which takes race, ethnicity, and other factors into account to help increase the diversity of the student body.

The GM brief argues that "consideration of race in university admissions furthers a compelling interest in educating students and training them to function in the global marketplaces," and that "elimination of affirmative action in leading educational institutions would deprive businesses of the well-trained minority candidates who are essential to our nation's economic success."

GM vice chairman Harry J. Pearce further explained:

> In doing our research on whether GM should involve itself in this lawsuit, we have been impressed with a growing body of research that concludes that college students who experience the most racial and ethnic diversity in classrooms and during interactions on campus become better learners and more effective citizens. Those are exactly the types of persons we want running our global business—better learners and more effective citizens.[16]

Such cross-border perspectives need to inform not only our admissions policies, but also course content itself. At Alhambra 2000, we were especially inspired by the presentation of Nathalie Aime, who teaches at a school in Réunion, an island off the coast of Africa that forms an overseas department of France. Her curriculum, "Atelier de Pratique Scientifique," is team-taught by teachers in math, physics, French, Spanish, and art.

With symmetry as unifying thread, they study crystallography, mosaics and friezes, musical canons, novels, and architecture. The approach is broad: One week they might learn HTML and computer graphics to create artwork and Web pages; another week they might visit a local sugar factory to study the crystallization process. They have even journeyed to Europe to view the Moorish palaces of Spain.

When our coursework delves into the global diversity of human culture, we begin 'breaking down walls.'

In the United States, a similar multidisciplinary approach to exploring different cultures guides the Mathematics Across the Curriculum (MATC) project based at Dartmouth College. The NSF-funded project, which has impacted thousands of students at Dartmouth and collaborating institutions, has brought together nearly 200 faculty members from such disciplines as mathematics, literature, history, philosophy, art, art history, biology, geology and engineering, producing so far over 75 modules, books, and videos.[17] Among these units are those focusing on the use of pattern and symmetry in African, Islamic and European cultures.[18]

Other materials have been developed to assist instructors wishing to incorporate multicultural approaches in their teaching. In mathematics, the new book *Using History to Teach Mathematics: An International Perspective*[19] is based on papers presented at international conferences in Seville, Spain and Braga, Portugal in 1996.

In addition to wide-ranging discussions of historical and multicultural approaches in education, the volume also includes material on the use of history in teacher training, as well as examples of recent historical scholarship in mathematics, such as George W. Heine III's essay "The Value of Mathematics: A Medieval Islamic View."

Alhambra 2000 participant Alex Hahn of the University of Notre Dame has written a general calculus text organized around episodes in the history of Mediterranean and European mathematics.[20] Books have also been developed for use in middle and high school classrooms[21], and there is an instructional video, *Arabesques and Geometry*[22], that was filmed at the Alhambra itself.

When our coursework delves into the global diversity of human culture, we open up a range of opportunities for "breaking down walls." Such efforts help link what is learned in a particular discipline with broader questions of science and culture, showing that all knowledge is interwoven, and that wielding this knowledge has practical consequences on an international scale.

A sense of mutual respect and understanding is fostered when students learn that inspiring contributions to human achievement have been made by every nation on the planet. Coursework that treats these varied contributions lays the basis for students to better grasp the point that there is social unity in multiplicity, an understanding that is sorely needed now in our fractured and fractious world.

I opened this essay with a quotation from Rubén Martínez in which he expresses fear of the gut-wrenching experiences when people from different races and nationalities are thrown together by the forces of the new economy. The conflict and strife seen in places like southern Spain, where Moroccan immigrants have been greeted by howling mobs, is certainly real enough.

But perhaps the most "terrifying" thing about race, to use Martínez' word, is that if the terms of the battle do not get drawn on a far higher level than these, we are doomed to stagnate as a society. Seeing the diversity and intermixture of cultures as a curse and a problem, rather than as an opportunity and a gift, doesn't move us toward a greater embrace of peoples and ideas that will be so crucial for society to flourish.

The Alhambra leaves us with a powerful lesson here, as well. After centuries of assault, the fortified complex finally fell to the armies of Ferdinand and Isabella in 1492, the same year they dispatched Columbus westward in search of gold and spices.

This was the last Arab stronghold in Europe; the Christian conquest of the Alhambra marked the end of Moorish society on the Iberian peninsula. In Granada, Cardinal Cisneros had the Islamic library torched; non-Christians were hounded from the city; and the silk industry collapsed.[23] For the first time, talk of "race" became widespread in Europe.[24]

Ironically, the beginning of Spain's Age of Gold was in fact the beginning of its long, deep decline.[25] The strange fruits of ethnic cleansing included the enslavement of Caribbean, Mexican and African natives, on down to the xenophobia of Franco and the anti-immigrant mobs seen today in southern Spain.

By way of contrast, I like the spirit of Zadie Smith, a young British novelist from a biracial family in London, whose novels are being compared to those of Charles Dickens, Martin Amis and Salman Rushdie.

In an interview, she distinguished herself from many of her compatriots by revealing her fantasy of learning several immigrant languages that would open up to her the as-yet-inaccessible London world of polyglot shops and alleyways.

"But you say that to some people in England and it is like their worst nightmare—that anybody English should partake in a culture which they see as a kind of invasion," she said. "I don't see immigration as an invasion.... I see it as a gift. It's obviously a good thing that people spend more time in each other's lives. And anybody who doesn't think that is ... well ... it doesn't matter what they think because they are swimming against the tide anyway. And they're lost."[26] ■

Endnotes

[1] Martínez, 2000, 11-12.

[2] Simons, 2000.

[3] Cohen, 2000.

[4] Jackson, 2000, 554-5; Struik.

[5] Maslen, 2000.

[6] Jackson, 2000, 555.

[7] Dillon, 2000.

[8] López Gómez, 1992.

[9] Dickie, 1992, 96.

[10] Brend, 1991, 19.

[11] For more on the use of symmetry and pattern in Islamic art, see Özdural, 2000; Walls, 1990; and the Website of The Textile Museum and The Math Forum.

[12] Nasr, 1968, esp. Introduction.

[13] Rouse Ball, 1908, in Joseph, 1992, 4.

[14] Kline, in Joseph, 1992, 5.

[15] Duhem, in O'Connor and Robertson, 1999.

[16] Doyle, 2000. The GM amicus brief, and extensive information on the UM admissions lawsuits, is available from the University of Michigan Website.

[17] Wallace, 2000.

[18] Dartmouth College Website.

[19] Katz, 2000.

[20] Hahn, 1998.

[21] See, for example, Alcoze et al., 1993; Lumpkin and Strong, 1995.

[22] Costa and Gomez, 1999.

[23] Dickie, 1992, 100, 103, 97.

[24] Sollors, 2000.

[25] Carew, 1992; Carr, 1992.

[26] George, 2000.

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