Increasing Minority Representation in the Mathematical Sciences: Good models but no will to scale up their impact

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Abstract

Across the nation, in the mathematical sciences communities–applied and pure mathematics, statistics, computer science and the computational sciences – established misconceptions are routinely used to justify the problem of under-representation of US Latinos, Native Americans and African Americans in the mathematics professoriate. A common view among academics is that the problem of under-representation is unsolvable *within our lifetime* because of the shortcomings in mathematics education at the K-12 levels. Statements such as, "Until these issues are resolved there is nothing that we can do," are accepted axioms. Prevalent explanations put the blame as far away from university communities as possible. This view ignores a history of cumulative successful efforts carried out by long-term partnerships between federal agencies and universities over the past two decades. National Science Foundation funded efforts like those established via the *Louis Stokes Alliance for Minority Participation* (LSAMP) have indeed changed the national mathematical sciences landscape when it comes down to issues of under-representation at the undergraduate level. LSAMP has *dramatically* increased the pool of US students (minorities and non-minorities) with bachelors' degrees in science, technology, engineering and mathematics (STEM). In the process, LSAMP has established a significant (growing) pool of US students available to programs like IGERT[1], VIGRE[2] and AGEP[3], ready to tackle the rigors of a graduate level education in the mathematical sciences. In this essay, we discuss the elements of a framework used (and in use) to increase US minority representation in the mathematical sciences since 1996. Elements of this model can be expanded or modified to alter the current landscape of under-representation in the professoriate. An irreversible positive shift can be carried out by "academicians" like us over a *relatively* short time scale that will bring the promises of our democracy also to US underrepresented minorities. Our model illustrates the obvious - that is, that the current system of exclusion, regardless of its rationale, initial conditions and past history, can be obliterated as long as the issue of under-representation becomes a *national* priority. We live in a society that continuously reinvents itself in the presence of new challenges. Why can't we find a systemic solution to the problem of inequity and under-representation in academia?

1 Mathematical Theoretical Biology Institute

1.1 A Little Bit of History

William Yslas Velez[4] has often challenged elite institutions to find ways of increasing minority representation in the mathematical sciences. This challenge has been taken up by Cornell

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[1] Integrative Graduate Education and Research Traineeship
[2] Vertical Integration of Research and Education
[3] Alliances for Graduate Education in the Professoriate
[4] Bill was the President of the Society for the Advancement of Chicanos and Native American in Science (SACNAS) in 1996. Bill is a distinguished professor of mathematics at the University of Arizona and a recipient of a White House Award for his documented efforts to mentor and support minority students. Rice University Professor Richard Tapia, the foremost US minority mentor of applied mathematicians, has also expressed similar views

University[5]. Bill introduced us to Jim Schatz[6] for whom the *absence* of American minority groups in the mathematical sciences is a matter of national security and deep personal concern. Thus, with the advice of Bill and the encouragement of Jim, a plan for developing a mentorship model that would be tried at a *Hispanic serving institution* in the summer of 1996, was drafted. The University of Texas El Paso seemed like the ideal place. We had met its President Diana Natalicio whose commitment to diversity is a matter of record and its faculty included an outstanding statistician, Javier Rojo[7], who immediately joined these efforts. We began to plot how to make UT El Paso[8] a national model for the training of US underrepresented minorities in the mathematical sciences. Bill also introduced us to a pure mathematician, Herbert Medina[9] whose interests in undergraduate education and diversity were matter of record. It was agreed that the summer research experience would be held at UT El Paso and after email "meetings" we were ready to submit a NSF proposal that would support *ten* students (the same number that we hoped NSA[10] would support) at our (REU[11]) program in applied mathematics. Unfortunately, the Mathematics Department at the University of Texas El Paso did not find the model compelling. Facing a NSF grant deadline in less than 24 hours away, we called Cornell's university provost, Don Randel[12] and requested his support for a *revised* version of our effort that considered a change in site, from UT El Paso to Cornell University. Don *instantly* provided the economic support and encouragement needed to get this project off the ground. Don had no doubts that this plan would set up a national mentorship model in the mathematical sciences. Needles to say, he was happy to see Cornell University take on a leadership role. The need for a continuous agent of change based on research at the interface of the natural and social sciences became obvious. Hence, the Mathematical and Theoretical Biology Institute (MTBI) was established as a research engine for mentorship and research and with its won summer institute. Hence, MTBI was born with the strong institutional support from the Office of the Provost at Cornell University in 1997. In 2004, MTBI moved to the largest Hispanic *research* serving institution, Arizona State University. The Office of the Provost and the President of Arizona State University have enthusiastically supported MTBI program and expansions.

1.2 The Mathematical and Theoretical Biology Institute (MTBI): a brief perspective

The goal of MTBI's programs is to increase the number of underrepresented US minorities with doctorates in the mathematical sciences or related fields. In line with our scientific interests in the field of mathematical biology[13], we agreed that this effort would be carried out within a research and mentorship institute that fosters and instigates innovation at the interface of the mathematical,

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[5] Carlos Castillo-Chavez (CCC) was member of Cornell University faculty from 1998 to 2003 where he was a member of the graduate fields of applied mathematics, biometry, epidemiology, ecology and evolutionary biology, statistics and theoretical and applied mechanics.

[6] At that time, Jim was the Chief of the Division of the Mathematical Sciences at NSA. He is now its Deputy Director of Research.

[7] Javier Rojo moved a few years later to Rice University where he currently leads one of the premier undergraduate research programs in statistics. At Rice, he is changing the graduate student landscape in the statistical sciences.

[8] UT El Paso had been awarded an NSF grant that would allow it to become a Minority Institution of Excellence in STEM fields.

[9] Herbert Medina collaborated in this project in 1996 and spent 1997 co-building a similar program, SIMU, but with an emphasis in pure mathematics. Herbert Medina and Ivelisse Rubio's program made tremendous contributions to the training of minority students in the mathematical sciences from 1998 to 2002 from its base at the University of Puerto Rico in Humacao.

[10] National Security Agency

[11] Research Undergraduate Experience

[12] Don left a few years later to become the twelfth president of the University of Chicago, a position that he just left after six years to become the President of the Andrew W. Mellon Foundation.

[13] Fred Brauer mentored CCC in applied mathematics at the University of Wisconsin. Fred has mentored MTBI students for at least 6 summers. Simon A Levin, the premier mentor in the field of mathematical and theoretical biology, was CCC's postdoctoral mentor. Simon and Fred have continued to mentor CCC for the past two decades.

social and natural sciences.

The absence of US Latinos, Native Americans and African Americans in the mathematical sciences at nearly every institution made it imperative that a national research mentorship program of the highest standards be created to increase the national number of Ph.D.s in fields where mathematical, computational and modeling skills play a critical role. MTBI's summer research experiences have since provided the *research* and *leadership* skills needed by US minority students. Our alumni *know* that they can succeed in *any* graduate program. MTBI's collaborative learning model has succeeded in increasing the pool of future scientific and academic leaders from the existing pool of underrepresented US minorities, in the mathematical sciences, created by programs like LSAMP.

Large educational lapses and outright failures at the K-12 level have resulted in gaps and shortcomings in the mathematics education a millions of Americans. At this level, large losses of mathematical talent, particularly among underrepresented US minorities are the norm. However, we do **not** need to wait for *somebody* to solve the systemic educational problems at the K-12 level before we take on the responsibility of tackling these issues at a level where we, college professors and administrators, can make a difference immediately. It would **not** be a monumental task to increase *dramatically* the representation of US citizens and residents, particularly underrepresented minorities and women, in all graduate programs in the mathematical sciences today. Recruitment efforts into the ranks of graduate students in the mathematical sciences are time consuming but they can be (and have been successful at some institutions) because there is, in fact, a *large pool* of under-represented minorities who have enrolled and are about to earn their degrees in the mathematical sciences.

When it comes down to failures in recruitment, it is unacceptable to continue to use arguments whose only goal seems to be that of justifying a record of our failures over the past four decades. The scientific American enterprise is not known for arguments that justify failure. How is it that arguments that justify such failure have become the norm when it comes to issues of under-representation in STEM[14] fields?

1.3 MTBI: a brief look at the numbers

For eleven years (MTBI) has mentored through its sequential summer research experiences a diverse group of undergraduate (277) and graduate (31) students. This population includes a high percentage of underrepresented US minorities. MTBI brings primarily juniors and/or seniors from mostly "non-selective" colleges and universities. Students who may not have considered graduate school as a real possibility in their future. MTBI participants have either a solid, very good or outstanding academic record. Most if not all applicants have a clear desire to find out what role if any mathematics plays in solving problems of importance to our society. *Naturally*, establishing mentorship programs that take advantage of the deep social concerns of US minority students are bound to become extremely attractive to students from underrepresented US minority communities.

MTBI's alumni have contributed to the establishment of successful minority graduate communities of students at the University of Iowa[15], Cornell University and Arizona State University. MTBI alumni have helped the faculty at these institutions establish and maintain a critical mass of US underrepresented minority students in their graduate programs. MTBI has also

[14] Science, Technology, Engineering and Mathematics.

[15] A note of clarification is in order, although MTBI is proud to have provided a large pool of US minority applicants to the department of mathematics at the University of Iowa, the fact remains, that most if not all of the credit should go to its mathematics faculty and departmental leadership who have welcomed, mentored, supported and graduated these students.

sent a small number of minority graduate students to various other universities. The list includes Harvard, Princeton, Stanford, Michigan and other equally recognized institutions. The first "large" crop of MTBI alumni completed their Ph.D. degrees in the mathematical sciences in 2005. They are entering the scientific enterprise primarily through the postdoctoral route. Their numbers however small represent a significant perturbation of past steady states. In 2005, MTBI alumni received 10 Ph.D.s in the mathematical sciences, 7 of which were awarded to members of underrepresented minority groups[16]. Seven hold postdoctoral positions (including six underrepresented US minorities) at selective institutions and one a tenure-track faculty position in Puerto Rico. The 2005 class of MTBI Ph.D.'s includes four "Latinas" and one African American woman. In other words, a program that has catered to 277 undergraduates has dramatically increased the national production of US Latinos (by 60 percent, see below) who have primarily undergraduate degrees from non-elite institutions. These graduates now have a solid opportunity to join the faculty ranks of research universities, if they choose to do so.

1.4 Increasing diversity in the sciences

The first step in achieving the goal of MTBI/SUMS[17] is to increase the number of under-represented minorities in the mathematical sciences at the graduate level. MTBI/SUMS has sent 130 students from *underrepresented minority groups* to graduate school over its first *ten years*[18] and a total of 169 students overall. Furthermore, 52 percent have been females, including 65 from minority groups. In the years 2001 and 2002, prior to MTBI/SUMS producing Ph.D. graduates, the U.S. awarded *an average* of 10 Ph.D.s to US Latinos[19]. MTBI/SUMS efforts have significantly increased the national rate of production of U.S. Ph.D.'s among underrepresented minority groups. In 2005, MTBI/SUMS alumni received 10 Ph.D.s in the mathematical sciences, seven of which were awarded to members of underrepresented US minority groups. This is almost a fourth of the national total output for that year. Of the 10 total MTBI/SUMS alumni Ph.D. graduates in 2005. Seven, including six from underrepresented US minority groups, took on prestigious postdoctoral positions and the other became Assistant Professor at the University of Puerto Rico, Mayaguez campus. Looking at female graduates, MTBI helped produce one third (5 out of 15) of the total female underrepresented minority Ph.D.s for 2005. Four of those five were Latinas, over half of the national production (4 out of 7). The 2006 class of MTBI Ph.D.'s include at least 10 graduates with an equivalent record of success and overwhelming US minority representation.

MTBI/SUMS alumni are prolific. They have coauthored *111* technical reports over the past eleven summers. These reports are often continued or extended or expanded into research manuscripts during the academic year. Several reports have served as instigators of highly innovative research. The bibliography includes a list of *ten* recent refereed publications where MTBI alumni played a fundamental role and where their interests on the use of mathematics to address issues of social equity and opportunity—the promises of our democracy—are obvious. This collection of articles is but a fraction of the research *instigated* by MTBI/SUMS over the past decade.

The indicators of future and current successes are visible. Twenty-four MTBI alumni have enrolled in a mathematical sciences program at Cornell University since 1996 and nearly ninety

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[16] Latinos, or African-Americans, or Native Americans who are US permanent residents or US citizens.

[17] The Institute for Strengthening the Understanding of Mathematics and Sciences or SUMS is MTBI's partner. Both merged in 2004 and both are under the direction of CCC. SUMS Institute is a winner of a 2003 Presidential Award (White House) for Excellence in Science, Mathematics and Engineering Mentoring.

[18] This number does not include the admission to graduate school of members of the summer of 2006 MTBI class. However, we are off to a good start: eight MTBI/SUMS alumni from the 2006 class are attending graduate school.

[19] The data for national Ph.D. graduates were obtained from the AMS notices http://www.ams.org/notices/200602/05firstreport.pdf

percent of those who enrolled in a Ph.D. program will complete it[20]. The mathematics department at Arizona State University has enrolled 24 US Latino and five African-American students to its graduate program in the mathematical sciences—a group that includes 24 MTBI alumni. The total number of MTBI alumni at ASU is now 34. Fourteen underrepresented minority students (MTBI alumni) have enrolled in a mathematical sciences program at the University of Iowa[21] this number does not include MTBI alumni who are not minorities who also have enrolled at the University of Iowa. These three groups of MTBI alumni form the nuclei of a close-knit community of minority scholars at three *research* institutions. MTBI alumni know each other, get together at annual professional meetings and their network is impacting the training of future mathematicians, particularly those from underrepresented minority groups.

MTBI's move to a State Institution (ASU) has facilitated the expansion and implementation of its mission. MTBI/SUMS mentorship efforts now begin at the high school level. SUMS staff has mentored 2,095 high school students through its Mathematics Science Honors Program (MSHP) over the past 21 years. MSHP students are quite diverse. Sixty percent participants have been female. Hispanic and Native American students account for the largest ethnic minority group percentage, *at fifty-one and eighteen percent*, respectively. Thirty-one percent of the students who participated in MSHP attended two or more summers consecutively, earning up to twelve credits in the three summers prior to attending ASU as freshmen. Almost *sixty percent* of MSHP participants have attended ASU after high school graduation. There are currently over 350 MSHP students attending ASU, with fifty-six percent female students and forty nine percent Hispanic students representing the largest gender and ethnic group respectively. The Ira A. Fulton School of Engineering has the highest percentage of enrolled MSHP students at thirty four percent, followed by the College of Liberal Arts and Sciences at twenty four percent. Additionally, students who participate in MSHP tend to have higher grade point averages and retention rates than those students who did not participate in the program. The standard grade point average (GPA) for a current non-MSHP ASU student is 3.01 while the average GPA for a current MSHP ASU student is 3.15.

Four Presidential Awards for Excellence in Science, Mathematics and Engineering Mentoring have been associated with MTBI/SUMS. The first (1996) to the late Joaquin Bustoz Jr., founder of SUMS, the second (1997) to Carlos Castillo-Chavez, Director of MTBI/SUMS, the third (1998) to Armando Rodriguez, Professor of Electrical Engineering and a strong contributor to MTBI/SUMS, and the fourth (2003) to SUMS itself.

MTBI/SUMS alumni are beginning to be hired into faculty positions and evidence of future patterns of secondary recruitment have already emerged. The establishment of the Applied Mathematical Sciences Institute[22], by MTBI alumni Erika Camacho and MTBI graduate mentor and former summer Director Steve Wirkus in 2005, provides a vivid example. One of our most distinguished SUMS graduate is Professor Trachette Jackson who is now a tenured associate professor of mathematical biology at the University of Michigan.

1.5 Challenges in implementation

This article articulates some of the elements of MTBI's successful model in an attempt to demystify the mechanisms behind its successes. We hope that the portability of MTBI's model or its elements are obvious but that their implementation, as with most good efforts, requires the

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[20] Two students enrolled in MS programs and had no plans to complete a Ph.D.; one enrolled in the Ph.D. program, did not complete it because of a serious family problem.

[21] Its mathematics department is a winner of a \$2005\$ Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring

[22] http://www.amssi.org/

participation of committed individuals[23] and the resources and support of agencies, foundations and university administrations. More importantly, it requires the will of the mathematics communities, which will not become a major force of *enduring* change until this effort becomes a national priority. The US has never failed at recruiting committed individuals capable of successfully carrying out an endeavor considered to be in the best national interest. Hence, the major roadblock lies in our inability to accept that under-representation is a major national priority whose solution deserves the long-term commitment given to similar national challenges. Clearly, there are effective models whose implementation would initiate the required innovation required to solve the problem of under-representation. Unfortunately, our national leadership (political and academic) has yet to show the will to support the implementation of the large scale solutions that we know will do the job. Thinking “big" and offering successful systemic approaches is not highly supported when it comes to addressing the issues of under-representation at the highest levels in the mathematical sciences—albeit it has been done at the K-12 level. This is actually in direct contrast to the standard policy of recommending and encouraging support for the most *successful* scientific projects.

Why don’t we face the challenges of US minority under-representation in academia head on? Part of the issue lies in the perspectives and visions of scientists who recommend funding decisions. Membership in academia automatically qualifies an individual as an expert in the development, implementation and evaluation of models designed to address our tragic educational shortcomings particularly those associated with the recruitment and retention of Americans (at the graduate level) in the mathematical sciences. Despite decades of failures, a large percentage of the mathematics community believes that the problem of under-representation is “easy" to solve, or that it is not a problem (graduate schools have enough foreign students), or that students who do not come from elite programs should not go to graduate school (“natural selection"). Several members of the mathematical community do not understand the importance of differentiating between US minorities (those that we are responsible for educating) and foreign nationals. The consequences of our inability to differentiate between these two populations and/or dismissing the problem as irrelevant or out of our sphere of interest are *immense* in a democracy. We cannot validate a society where about one third of the US population has no representation and, consequently no role models or champions in US academia. Let’s try to imagine today a university system with no women!

2 Model’s description

This section expands on the model description provided in our article “The New American University: Mentorship in the Mathematical Sciences." The article in question will appear in “Models that Work" a volume that will be published by the American Mathematical Society.

2.1 Common language

Students are assumed to be at least familiar with elementary calculus (2 semesters); have been exposed to linear algebra (eigenvalues and eigenvectors); have some “feeling" for probability, basic statistics (probability densities and distributions, random variables, Baye’s Theorem and expectation), birth and death stochastic processes, as well as some familiarity with a programming language. The cooperative nature of the MTBI environment is such that some

[23] The faculty members are the most committed. We have had several outstanding individuals involved over the past eleven summers. Although we can't list them all, it is worth noticing that our premier mentors include the following extraordinary professors: Baojun Song, Montclair State University who has mentored students for ten summers; Steve Wirkus, California State Polytechnic University at Pomona (eight summers); Abdul Aziz-Yakubu, Howard University (six summers); Christopher Kribs-Zaleta, University of Texas at Arlington (six summers); Steve Tennenbaum, Innovative Emergency Management, Inc. (seven summers); and Carlos Hernandez Suarez, Universidad de Colima in Mexico (six summers).

weaknesses in these areas are not critical. The first three weeks of the program are devoted to the study of dynamical systems in the context of ecology, epidemiology, immunology and conservation biology. Furthermore, students learn thorough carefully prepared computational laboratories on how to program in Matlab (The Mathworks Inc.) and XPP while becoming proficient with Maple, Minitab and $\LaTeX$.

The students are responsible for sixteen extensive complex sets of problems that are closely tied in to the lectures. “Review" lectures are provided on the essentials of linear algebra and probability. The preparatory phase ends with a pre-project that forces the students go beyond the material covered in class. Typically, the pre-project involves the study of a dynamical system with identified dynamics at two highly distinct temporal scales. Bifurcation analysis, simulations and the interpretation of model results are at the heart of this exercise. Students are involved in lectures, problem and modeling sessions and computational labs for an average of five hours per day.

2.2 Salt and pepper

Relevance seems to be the key to motivation and success. A modeling seminar is conducted twice a week by program alumni (undergraduate and graduate students). Alumni describe the process that they followed as participants in identifying and selecting their own project as well as in convincing a group of colleagues (three to four) to join efforts. Alumni put an emphasis on identifying a key question - a process that precedes the selection of the appropriate modeling framework. Students have often encountered difficulties when they insisted on using a specific methodology without taking into consideration its appropriateness for their question. During the first weeks, distinguished researchers provide sets of two-to-three 90-minute connected lectures supplemented with relevant problem sets. These lectures highlight interesting “pure" mathematics or non-trivial applications. Throughout the process, students are assisted by graduate students and resident faculty and highly encouraged to work together. Following the general “Oberwolfach”[24] model, the lectures, seminars and talks are followed by a community dinner where students interact with faculty and graduate students. Paper tablecloths serve a double function - they are also used as writing or drawing pads. Napkins are not sufficient in these learning communities!

2.3 Absence of hierarchies

By design, the research agenda of this summer institute is set by the *undergraduate* participants. This tradition was begun in 1997 when the institute was in its second summer. Today, it is not uncommon to see students arrive with their own projects at the start of “math camp”. Such students try to sell their projects to two to three additional participants during the first three weeks. There are no rules regarding the formation of such groups except that they made up of three to four individuals. Once the groups have been formed (no faculty supervision) students begin to present orally their projects to a group of faculty, graduate students and visitors. The initial role of these sessions is to help students narrow the scope of their project. Efforts to identify a doable question are at the heart of these sessions without attempting to alter the overall goal of the students project. Typically initial suggestions are: What is the impact of alcohol on brain activity? What are the dynamics of eating disorders? What conditions will guarantee the survival of the monarch butterfly? What are the effects of different social structures on the spread disease of HIV in Nigeria? Once a question that captures the essence of the students project is selected, efforts to build an appropriate model are carried out. These modeling efforts may move us into the world of networks or dynamical systems broadly understood to include stochastic processes or simulations. During this process, the students are assigned faculty advisors and

[24] Oberwolfach, located in southern Germany, is one of the most famous retreats where mathematicians get together to exchange ideas in an environment that, by design, facilitates interactions between established and young scientists

graduate student support. The incorporation of these individuals is based on the desire of the faculty to get involved in the enterprise and the interest of the graduate student in the project. The project dynamics including group composition, research question, and model selection are in the hands of undergraduate students. Participants work on problems for which faculty participants do not have the answer. To sum it up, faculty, graduate students and undergraduate participants become collaborators, and partners in crime.

2.5 Meeting Expectations

The following next three weeks are driven by the intensity of the participants to provide an answer to a relevant question. Regular open meetings are conducted where each group presents and defends their effort. On some occasions, students have had to make dramatic changes to their models. After three weeks a series of results (numerical, analytical and statistical) that shed some light onto the question of interest are completed. Students then work hard on writing a technical report (25-45 pages) that captures the problem, the model, the methods, and their results.

2.6 The product

The participants conclude their efforts with a technical report (111 in eleven years), prepare a thirty-minute presentation, and highlight their research on a poster. This year, the program began on June 6, 2006 and concluded on July 29, 2006. Seven groups of participants made oral presentations of their results at the joint meeting of the Society for Industrial and Applied Mathematics (Life Sciences Group) and the Society for Mathematical Biology--held in Raleigh North Carolina from July 30 to August 4, 2006. Seven posters were presented. These posters were also presented at the annual SACNAS meeting in Tampa, Florida (October 27, 2006) and will be presented at the annual AMS meeting in January of 2007. Students regularly have presented their research at their universities and at local conferences during the academic year, following the completion of the project. An average of 2-3 awards per year have been given to MTBI projects.

2.7 Relevant Subtle Issues

Creating a community of scholars has to be done with care. For example, minority students at various universities are being awarded fellowships provided by the Alfred T. Sloan Foundation. It has been documented that students with fellowships often tend to do less well than those without them because students with fellowships are often not integrated into the appropriate scientific communities[25]. It is not uncommon in universities where space is a highly contentious issue to provide a desk, a place in the community, exclusively to students who have a paid job to do[26]. The absence of a space in a university setting naturally isolates minority students and prevents them from learning from and teaching to others. Faculty administrators facing the pressures of finding space for a large number of part-time faculty associates, TAs and RAs[27] (funded by faculty grants), place no priority on implementing practices that would increase the retention and graduation rates of all their students. Eliminating practices that prevent indirectly funded students from participating in the daily life of a mathematical community are not negotiable.

Ehrenberg in his article in this volume, identifies a problem that was unknown to us, namely that graduate students who publish early are more likely to drop out, but also more likely to get a tenure track position. He adds that graduate student publication is a good indicator of early career publication. Here, we speculate as to why this may not be an issue in the mathematical sciences. In mathematics there is still (albeit fortunately fading out or at least that is our hope) a tradition of not getting a *real* advisor until one has passed the qualifying exams, a process that often takes

[25] Ted Greenwood, Sloan Program Director, personal communication
[26] Teaching or Research Assistantship
[27] Typically, TAs have the highest priority when it comes down to having a desk; RAs get the remaining space

three to four years[28]. Not having a real advisor precludes access to research—the motivation for going to graduate school. For an increasing number of American students not getting involved in research from day one is a cause of despair and probably contributes to the drop out rates experienced among American students. What about early publications? These phenomena (publications before graduation) are relatively new in mathematics and yet a most do in applied mathematics. We have no access to the kind of data that would shed some light on its impact in the mathematical sciences. One would need to know the following: Are those students who publish taking longer to pass their exams? Are these students spending energy on publications that would not be part yet of their theses? We suspect the existence of quite a different pattern in the mathematical sciences than the one described by Ehrenberg but we have no systemic data to support this conjecture. MTBI alumni who have worked with CCC have completed their degrees with multiple publications (two to seven) directly tied to their own thesis research. Most CCC's Ph.D. students have passed their qualifying exams early partly because at Cornell University[29] these exams are not over-emphasized and because Cornell's graduate field requirements are minimal. At Cornell University, the quality of the education of each student is left primarily in the hands of the Ph.D. advisor who works closely with the student's Ph.D. committee (two additional faculty members) in setting up a first-rate educational experienced that is tailored to the needs and interests of all involved, particularly those of the student. This advisory group composed of three faculty members develops with the student a coherent plan that puts a high value on increasing the probability that the student will complete an outstanding Ph.D. thesis in his/her area of interest.

Perhaps, MTBI alumni have not experienced Eherenberg's dilemma because MTBI provides continuous mentorship to students from their undergraduate careers through graduate school. MTBI's model eliminates the isolation that a graduate may be experience during the early years while facilitating the publishing processes which is "learned" or experienced at the undergraduate level.

3 Successes

3.1 Creating infrastructure to sustain an increase in diversity

As successful as MTBI has been at increasing diversity in the mathematical sciences, MTBI is still only one program. Unless the changes that MTBI has created become self-sustaining and self-generating its impact will be short-lived. To this end, we believe that creating a large community of minority scholars that is committed to the issues associated with the problems of under-representation in the mathematical sciences is but one way. Such a community will provide the environment where minority success and minority recruitment into the sciences is natural – the norm rather than the exception.

3.2 Encouraging the development of the New American University

MTBI/SUMS philosophy adheres to the principles of the "New American University[30]", that is, MTBI is an institute that, like its home institution, ASU[31], wants to be judged by the quality of the research and academic accomplishments of its students and alumni rather than by the academic pedigree or the prior access to selective educational settings by its participants. Encouraging the development of this perspective is critical to the goals of MTBI because it directly addresses the disadvantages that many underrepresented minority students face. MTBI wants to be an institute whose alumni, while pursuing their scholarly and scientific interests, also consider "the public

[28] In math according to NSF the average time to a Ph.D. in the mathematical sciences is at least seven years
[29] CCC's first two Ph.D. ASU students will be graduating in May of 2007.
[30] http://www.asu.edu/president/newamericanuniversity/arizona/
[31] Here, we are paraphrasing ASU's mission but in the context of the work that is being carried out at MTBI.

good"[32]. MTBI wants to be an institute whose students, alumni, faculty, and staff transcend the concept of community service to accept responsibility for the economic, social, cultural, and environmental vitality of the communities they serve[33].

The success of MTBI in creating excellence in the context of social responsibility is best illustrated by the work of Erika Camacho and Steve Wirkus who, only a few years after graduation, have begun to give back massively to the mathematical community. Erika and Steve have set up a model learning community in just two years.[34]

4 Why haven't we been able to implement systemic change?

MTBI is a model that works. It has documented successes and it can be duplicated. So why aren't we seeing a lot more programs like MTBI? The answer, simply put, is that the professoriate does not have the incentives to do so and as a result, undergraduate students *must* be neglected.

Advancement and funding in academia does not come from mentoring successes, particularly at the undergraduate level, they come from research successes. Running a competitive research program requires getting the most "bang for your buck" in terms of publication results offset by cost and time. Time spent training undergraduate students is useless. Why train them when there are graduate students (mostly already trained internationals) who are capable of carrying out research immediately and with limited or no training. Faculty research programs bear a resemblance to sweatshops, which happen to be useful in producing the products that we want (publications) and they do it at the lowest possible price. The '*maquiladora'* model has brought immense benefits to our society because it is based on its ability to generate immediate results (production) at the lowest possible costs (paying trained scientists graduate students salaries). The model is unacceptable because it excludes the participation of a great percentage of US taxpayers, that is, it limits access to those who have built and pay for our research institutions.

The importance of the internationalization of scientific research is clear and obvious to any researcher who values knowledge. MTBI may be the only *undergraduate* research program that has supported *international* undergraduate students[35] every year. However, MTBI would not do it to the exclusion of *most* American students—the model used in mathematics departments at research institutions. We should not be in the business of supporting a society where underrepresented US minority students have no access to world's largest and most productive scientific and educational enterprise.

The negative consequences associated with the current educational system for American undergraduates are high. American students are neglected by faculty that spend most if not all of their time managing, as they should, their research operation ("*maquiladora*"). In a well-documented article by Zhang in this volume, he notes that the share of non-resident aliens enrolled in graduate programs in the United States rose from 5.5 percent in 1976 to 12.4 percent in 1999. Furthermore, his article also documents an even more pronounced increase in science and engineering (SE) fields. In the 1999-2000 academic year, non-resident aliens received 38.2 percent of doctorates awarded in the physical sciences, 52.1 percent of doctorates in engineering, 26.6 percent in the life sciences, and 22.8 percent in the social sciences. Finally, Zhang notes that recent data show that in 2002 about 26 percent of all doctorates awarded in American universities went to temporary residents[36], and in SE fields more than 32 percent of doctorates were conferred on temporary residents. A social divide has developed between undergraduates, graduates, and faculty. As a result, undergraduates in America are not receiving the training and opportunities

[32] http://www.asu.edu/president/newamericanuniversity/arizona/
[33] http://www.asu.edu/president/newamericanuniversity/arizona/
[34] http://www.amssi.org/
[35] 33 out of 277
[36] In this article by Zhang no data is provided on these percentages relatively to university prestige elite versus non-elite.

that they need to compete for these graduate positions. The current system becomes self-perpetuating - fewer Americans are selected because there are better-trained international students. There are better-trained international students because American undergraduates are neglected. Students trained abroad are sent to us ready for prime time and we need them because we continue to fail to give the same level of competitive training to our own undergraduates. In other words, we are the owners of a large percentage of the best research institutions in the world and yet can't produce competitive undergraduates, that is, students who can meet our graduate students admission requirements.

The current system is unlikely to be able to continue forever. The problem of using pre-trained international students has multiple dimensions. What if we experience drastic reductions on the rates of no return to their countries of origin[37]? Shouldn't we encourage their return to the countries that educated them? Or, in the future, will the undergraduate training of American students be exclusively in the hands of immigrants? There is evidence that the overall quality of undergraduate education that one can receive in China or India in STEM fields far exceeds the quality of average US STEM education that one can receive in the United States. If this continues, international students soon will not need us. Over the past two decades a large percentage of Chinese are getting their Ph.D. degrees in China and countries like Australia are now heavily competing with us for foreign graduate students.

The issue of role models is fundamental as well - what messages are American students getting? *That to be a good researcher or a mathematician you have to be born, raised, and educated elsewhere*! Recent data from the American Mathematical Society shows a similar trend among US Asian students. For minority students, who are already disadvantaged, all the difficulties that American undergraduates are having are magnified. Researchers who already don't have time to train undergraduates are not going to take extra effort to find, recruit and train minority students. If this is to continue, we need to create a new system or new faculty positions whose responsibility are to face the challenges of successfully educating American STEM students.

5 Cost

The issue of the cost of a program like MTBI was omitted on a first draft of this manuscript. David Burke, a professor of human genetics and a member of Genomics Training Center headed by Mike Boehnke at the University of Michigan brought it to our attention and suggested that we address it. The Michigan Genomics Center faculty has given a three-day workshop on genomics as well as long-distance mentorship to MTBI participants for the past five years. All mentorship activities involve intense faculty participation, that is, the participation of highly trained individuals. So what is the cost? Who pays for their time? When it comes down to research, universities pay for most of the research time of its mathematical sciences faculty. Typically, nine-month appointments (composed of 50 percent research and 50 percent teaching and service) mean that in general, NSF will "decide" who does paid summer research and who does it for "free". This has become an accepted practice in academia—albeit unwillingly. Training undergraduates to be ready for prime time is not less costly but, on the contrary, their training provides no tangible rewards. Typically, there are *no* immediate publications, no grants and no recognition when it comes to mentoring undergraduate students—particularly at research universities. Those in charge of salary increases or promotions do not value mentorship activities and so it would be suicidal to devote time training American students to do research. There are plenty of academicians at research and non-primarily research universities who would gladly shift a great deal of their time to the training of undergraduates but such a decision would bring negative responses by administrators. NSF and NIH need to put funds (not that much would be

[37] See the article by Oliva in this volume

required) that would support the careers of individuals who choose to train undergraduates to do research. Success would be measured by their ability to place these American students in graduate programs. Top research groups cannot do the job that is required *at the scale* that it is needed but there are plenty of researchers/professors who would do it if the rewards were there.

At MTBI the cost per student per summer is high—about 10K. However, this is not the *real cost* of each student as we do not account, in dollars and cents, for the time an effort put by individuals and groups (like the time given to MTBI by the Michigan's Genomics Training Faculty) in these mentorship efforts. The "cost" of each student who has been successfully placed in graduate school (that is, if we only consider students who have actually **received** an advanced degree) at 25K. This amount includes room, board, stipend (3K per summer) and paid mentorship efforts over an average of two and a half summers (five months). If we remove the stipend then the cost per student is about 17 or 18K. This amount is equivalent to the *tuition paid* at an elite university for one semester!

6 Support

MTBI/SUMS efforts have not been carried alone. MTBI received extraordinary support from the Cornell University's administration[38], the Center for Applied Mathematics and the Biological Statistics and Computational Biology Department. MTBI/SUMS has had no less support at ASU[39]. We have established a highly effective partnership with ASU's Hispanic Research Center[40]. Similarly, ASU's Mathematics and Statistics Department has not only embraced our efforts but has actively joined them. MTBI/SUMS successes have been possibly because of the leadership and hard work of all our partners, supporters, its staff and its summer faculty. However, at the end of the day it is the continuous funding by NSA, NSF and the Sloan Foundation[41] that have kept this effort alive long enough to make a difference.

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[38] Malden Nesheim, Don Randel, Biddy Martin, Frank Rhodes, David Call, Hunter R Rawlings III and W. Kent Fuchs

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[41] The encouragement and confidence given to MTBI by Barbara Deuink, LLoyd Douglas, Ted Greenwood, Jim Schatz and Michelle Wagner have played a critical.

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