

## **AC 2010-1403: STRENGTHENING THE K-20 ENGINEERING PIPELINE FOR UNDERREPRESENTED MINORITIES**

**Nancy Warter-Perez, California State University, Los Angeles**

**Jianyu Dong, California State University, Los Angeles**

**Eun-Young Kang, California State University, Los Angeles**

**Huiping Guo, California State University, Los Angeles**

**Mauricio Castillo, California State University, Los Angeles**

**Alexander Abramyan , California State University, Los Angeles**

**Keith Moo-Young, California State University, LA**

# Strengthening the K-20 Engineering Pipeline for Underrepresented Minorities

## Introduction

As the National Academy of Engineers (NAE) report on *Changing the Conversation: Messages for Improving Public Understanding of Engineering* revealed, there is a public misconception of engineers particularly among minorities.<sup>1,2</sup> The study reported that Hispanic boys in general believe that engineering has a positive effect on people's everyday lives but Hispanic girls believe that engineers are nerdy and boring. At California State University, Los Angeles (CSULA), a designated Hispanic Serving Institution, these findings are born out in the classroom where the overwhelming majority of Hispanic engineering students are male. Furthermore, while some Hispanic engineering undergraduates opt to pursue a master's degree, very few pursue a doctoral degree.<sup>3</sup>

The IMPACT LA Program, Improving Minority Partnerships and Access through CISE (Computer & Information Science & Engineering)-related Teaching, is an NSF Graduate STEM (Science, Technology, Engineering and Math) Fellows in K-12 Education Program designed to address these concerns. The program partners graduate fellows who are conducting master's level research in a CISE-related field with a middle or high school teacher from the East Los Angeles area. Fellows work closely with teachers to develop hands-on activities designed to enhance the educational experience of students and increase their interest in STEM-related fields. The NAE study found that female students in particular relate well to role models, and thus, the program actively and successfully recruited women and minorities graduate fellows for its second year. Of the nine fellows 44% are women and 56% are Hispanic.

The two primary goals of the IMPACT LA Program are to 1) change teachers, students, and parents' perceptions of engineers and encourage K-12 students to explore engineering and research careers, and 2) to enhance the communication and research skills of graduate fellows. To achieve these goals, during the summer workshop teachers participate in a wide range of exploratory research experiences designed by fellows to introduce teachers to their research areas. During the school year fellows expose students to their research in different ways including informal research discussions, videos showing fellows conducting their research, and by infusing research into hands-on activities.

In addition to trying to get more minority students into the engineering pipeline through our partnerships with East LA schools, MESA (Math, Engineering, Science Achievement), Great Minds in STEM (formerly HENAAC), and industry, the IMPACT LA program is working to strengthen the pipeline by recruiting minority undergraduate students from CSULA and other

institutions to pursue a master’s degree as an IMPACT LA fellow. The program then works with research mentors to encourage and prepare fellows to pursue a doctoral degree. In addition to helping fellows better communicate their research to a broader audience, training is provided to build the fellows’ professional development skills including time management, research presentation skills, and interviewing skills.

In this paper we will share our best practices in the IMPACT LA program on enhancing the pipeline to recruit minority students and prepare them for advanced degrees in engineering fields. We also present the preliminary assessment data to show the positive impact on K-12 students’ perceptions of engineers and on the professional development of our graduate fellows.

### Constituents of the IMPACT LA Pipeline

To strengthen the K-20 engineering pipeline for underrepresented minorities, specifically Hispanic students, the IMPACT LA program has formed partnerships with the Los Angeles Unified School District, the Partnership for Los Angeles Schools, MESA, Great Minds in STEM, local industry, and local PhD granting institutions such as the University of Southern California. In addition to providing a pathway for students, many researchers have commented that these partnerships are essential for helping to change perceptions of both higher education and STEM careers among the Hispanic community.<sup>4, 5</sup>

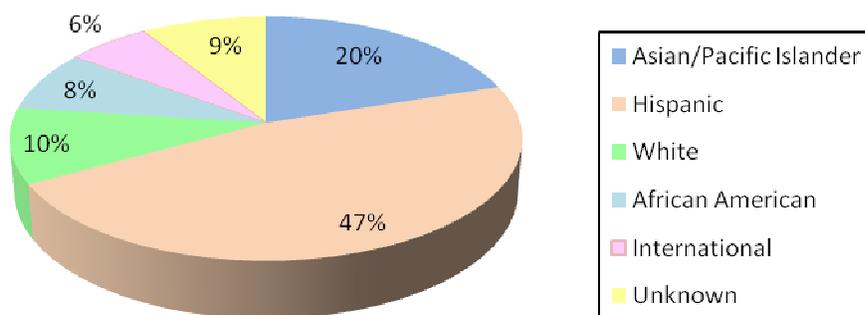
**Table 1.** Characteristics of Partner Schools for IMPACT LA Project (API refers to Academic Performance Index and ELA refers to English Language Achievement).

School Name	Percentage of Hispanic Students	English Learners	Free or reduced lunch	Academic Standing (2007 API )	ELA/Math (Proficient or above)
Hollenbeck MS	97%	40%	90.5%	589	22%/15%
Roosevelt HS	99%	39.3%	78.9%	557	8%/2%
Stevenson MS	99%	43.4%	90.3%	593	19%/19%
Marc and Eva Stern Math and Science School	98%	31%	90%	718	NA

The demographics of the middle school, high school and university partners are shown in Table 1 and Figure 1. From Table 1 it can be seen that more than 97% of all students at the partnership secondary schools are Hispanic. Furthermore, Table 1 shows some of the academic challenges these students face with proficiencies in math ranging from 2 – 19%. During our second year,

we have added a new partner school, the Marc and Eva Stern Math and Science School (Stern MASS), which is a charter school located on our campus. The students from all partner schools come from the same community and share similar language barriers and economic challenges. Yet, the performance (based on API scores) of students at Stern MASS as compared with those from the Partnership for Los Angeles Schools demonstrates 1) how parent support can dramatically impact the success of the students, and 2) the effectiveness of STEM focused high schools.<sup>5</sup>

Figure 1 shows the demographics of California State University, Los Angeles (CSULA), a designated Hispanic Serving Institution. The IMPACT LA program is working with the MESA and LSAMP programs to improve outreach to our partner schools, increase retention of students in STEM fields at CSULA, and promote students to pursue advanced degrees at CSULA and local doctoral institutions.



**Figure 1:** Student demographics at California State University, Los Angeles.

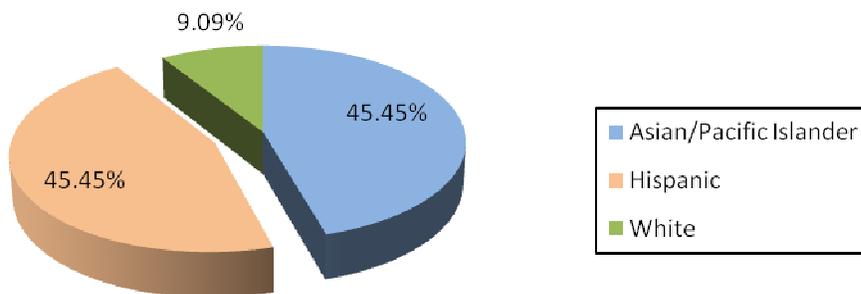
While the population of Hispanics in the United States is 13%, the population of Hispanics in STEM PhD Programs is only 4.8%.<sup>3</sup> Currently all IMPACT LA graduate fellows must complete their Master’s Thesis which is the highest degree offered by CSULA. To further encourage graduate fellows to pursue a PhD, the program supports fellows to attend both professional conferences and the NSF GK-12 National Conference to network with PhD students and doctoral research faculty. To date, fellows have published three papers<sup>6, 7, 8</sup>, presented five presentations at national conferences, and attended twenty conferences. Fellows are also encouraged to form GRE study groups. In addition, seminars on graduate school, how to present scientific presentations, and grant writing are held.

## Fostering Role Models

The IMPACT LA Program places graduate fellows, who are conducting masters-level research in STEM disciplines, into middle and high school science and math classrooms as visiting scientists and engineers. Working with their partner teacher and students, the fellows serve as role models introducing students to careers in STEM and sharing with them the opportunities and experiences of undergraduate and graduate study. For example, fellows have created videos of their typical day showing students the campus, their research lab, their classrooms, and their friends. In the videos, the fellows invite the students to visit campus where they will show them around.

Many studies have shown that the importance of changing the students' and perhaps more importantly their parents' perception of the higher education and STEM careers early in the students' education.<sup>9, 4, 5</sup> In addition to bringing the campus experience to the students via informal discussions and videos and increasing their awareness of STEM-disciplines and careers through research-related classroom activities, to reach their parents we are planning to have an IMPACT LA Open House this year. The Open House will have tours of the research labs, hands-on activities, and informational sessions about undergraduate and graduate opportunities and STEM careers.

Many studies have also stressed the importance of role models and mentors.<sup>4, 5</sup> During the second year of our program we actively sought out women and Hispanic graduate students to serve as role models. Figure 2 shows that since the start of the program, over 45% of the fellows have been Hispanic. Of the nine 2009-10 fellows 44% are women and 56% are Hispanic.

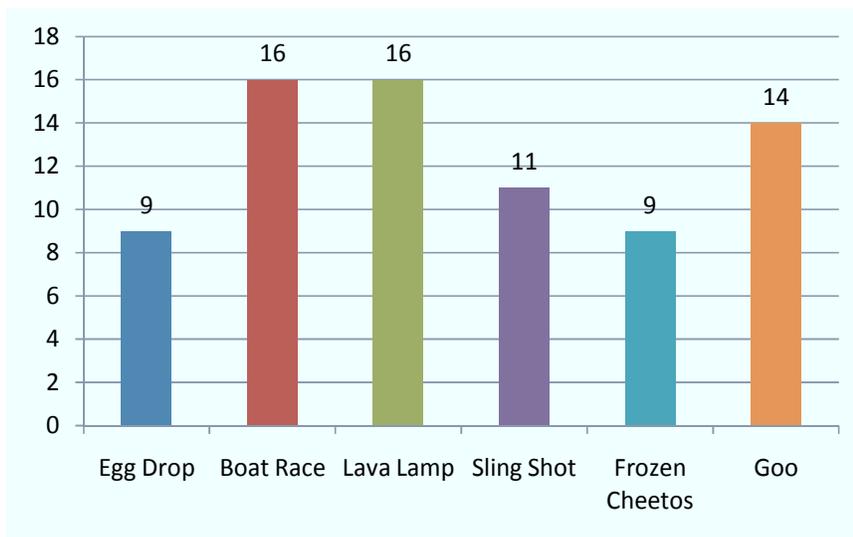


**Figure 2:** IMPACT LA Fellow demographics.

## Community Outreach

Community outreach is particularly effective among women and minorities.<sup>10</sup> To help prepare the graduate fellows for the classroom and to promote STEM to more students in the community, an IMPACT LA summer camp has been added at the culmination of our summer training workshop.<sup>11</sup> Each of the nine fellows led a hands-on activity and there were four group camp activities. Engineering activities included building Morse Code telegraphs, designing and building wind turbines and catapult-like sling shots, designing capsules to ensure the egg astronauts landed safely on Mars (the cement patio), and culminated with a cardboard boat race. Science activities spanned biology, chemistry, and physics including activities exploring the DNA of strawberries to eating, learning about polymers and goo, experimenting with density with water bottle lava lamps, and studying the states of matter while eating flaming hot Cheetos cooled in liquid nitrogen. Students also had fun with math games and creative button manufacturing.

The two-day science and engineering camp was a huge success among the 6<sup>th</sup> – 9<sup>th</sup> grade participants. Figure 3 shows the top-ranking camp activities. The word “fun” appeared in 33 of 43 camper responses to how they chose their favorite activities. All students indicated that they wanted to see these kinds of activities in their classrooms. Not only did they learn about science and engineering, but also the importance of teamwork. One camper commented “That it takes steps to make a product but when you work as a team you get done a lot faster.”



**Figure 3:** Top IMPACT LA summer camp activities.

## **Bringing Research into Classroom**

In the IMPACT LA Program, fellows serve as visiting scientists/engineers who partner with a science/math teacher working in the classroom for 10 hours per week for an entire year. The fellows bring their research into the classroom by working with their partner teacher to integrate their research into classroom activities, discussing with students how their research relates to different class topics, and by sharing their research experiences in the lab and at conferences with their partner teachers and students. The goals are to better prepare students for STEM courses in college by improving teacher and curriculum quality and to encourage more students to study STEM and expose them early on to graduate school and research.<sup>5,9</sup>

To help build strong partnerships between fellows and their partner teacher, workshops are held throughout the year. During the first week-long summer workshop, a series of research-related activities are conducted to help the teachers select a fellow and educate them on different areas of research in STEM. On the first day, fellows give a five minute research presentation to all teachers and the teachers go on a tour of the research labs. Afterwards teachers rank their interests in different research projects taking into account what will work well with their subjects. Based on that ranking, teachers participate in more in-depth research experiences with about half of the fellows. Once teachers are paired with their fellow, they participate in an even more in-depth research experience to help educate them about the fellows research so that they can work together to bring research-related activities into the classroom.

In addition to the research related hands-on activities and lesson plans, fellows expose students to their research via short research introductions, virtual lab tours, by inviting their research mentor to present to their class, and through sharing conference pictures and videos. One practice we use that was learned at the NSF GK-12 National Conference is to have students pose questions to experts in the field which the fellow brings to the conference. The fellow then video tapes the experts and shares the responses with their classes.

## **Changing the Conversation**

Oftentimes engineers and scientists become tongue-tied when asked to explain their work to the general public. One of the main benefits to the graduate fellows participating in the NSF Graduate STEM Fellows in K-12 Education Program, as opposed to other research fellowships, is the communication skills that the fellows develop and their ability to communicate their research with to a broad audience ranging from middle school students to experts in the field. To be effective in educating and influencing current students and teachers, the IMPACT LA Program trains students on effective science/engineering communication skills. Ultimately it is our goal to have these fellows be STEM ambassadors who are able to change the public's perception of science and engineering as they become experts in their respective fields.

Training students on effective communication occurs continually throughout the year. Students start their training in the Technology 494 class that helps them to understand how to effectively express their research to middle and high school students. Students get to apply what they have learned in this class during the summer camp. Since different groups of campers rotate through the activities, fellows have an opportunity to present their camp activity multiple times, each time adjusting their delivery style based on their interactions with the previous group. Throughout the year as fellows present hands-on activities to their classes, as they answer questions about science and engineering (one middle school pair of fellows has an “Ask a Scientist Box” in their classroom), as they share the latest news about science and engineering innovations, they are continually improving their communication skills.

Fellows learn how to deliver their research to a broad audience through developing and delivering different presentations for different audiences. At the beginning of the summer workshop students present a 5-minute presentation on their research to deliver to the teachers. Students practice this presentation ahead of time in front of the PIs and their peers who are from a broad range of research disciplines. Students also prepare a brief introduction of their research for their classrooms. When presenting their research at a national conference, the ability to relate their research to a broad audience also makes their technical presentations more engaging. During bi-weekly fellow meetings, fellows get an opportunity to present a 5 – 10 minute research presentation similar to one that would accompany a poster presentation. Not only do fellows get useful feedback from their peers and faculty but they also learn from other fellows about effective presentation strategies. Finally, fellows also prepare a two-minute elevator talks for the NSF GK-12 National Conference on several topics including 1) their research, 2) how they have brought their research into the classroom, and 3) how they have been impacted by the IMPACT LA Program. These two-minute elevator talks derive their name because they are brief enough that they could be shared with someone on an elevator ride. Whether on an elevator or not, preparing for these talks allows the fellows to effectively share their NSF GK-12 experience with the conference attendees including fellows, teachers, and faculty from other programs and with NSF program staff.

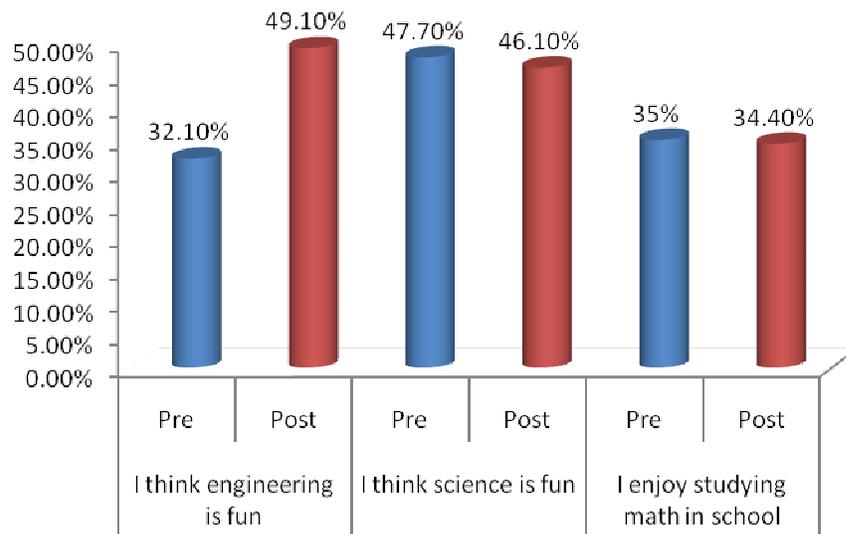
Recent studies by the National Academy of Engineering have stressed the importance of training engineers using consistent messages to change perceptions of engineers.<sup>1,2</sup> During our workshops fellows and teachers receive training on these messages and are continually encouraged to use them in the classroom and in their every day use. This training has also had a large impact on the PIs of the project. Fellows are encouraged to use the phrase that “engineers make a difference in the world” and to use words like discovery, design, create, imagination, innovation, and contribution when discussing engineering and science.

## Changing Students Perceptions of STEM Careers – Initial Assessment Results

During its first year, the IMPACT LA Program had three graduate fellows, one working with a robotics class at a partner middle school and the other with math classes at a partner high school. The research areas of the three fellows were related to computer science and engineering, namely machine learning, image processing, and bioinformatics. In these classes, pre and post surveys were conducted to measure the impact of the IMPACT LA Program on students' perceptions of and interest in STEM. 223 students participated in the pre-survey and 204 in the post-survey. Below we share some of our findings.

### *Perceptions of Engineering*

Figure 4 shows the impact of the IMPACT LA Program on the students' attitudes towards engineering, science, and math. It is encouraging to see that the fellows through their interactions with the students had a relatively significant impact on the students' perception of engineering. Before the fellows worked with the students, 32% thought that engineering is fun as compared to 49% at the end of the year.

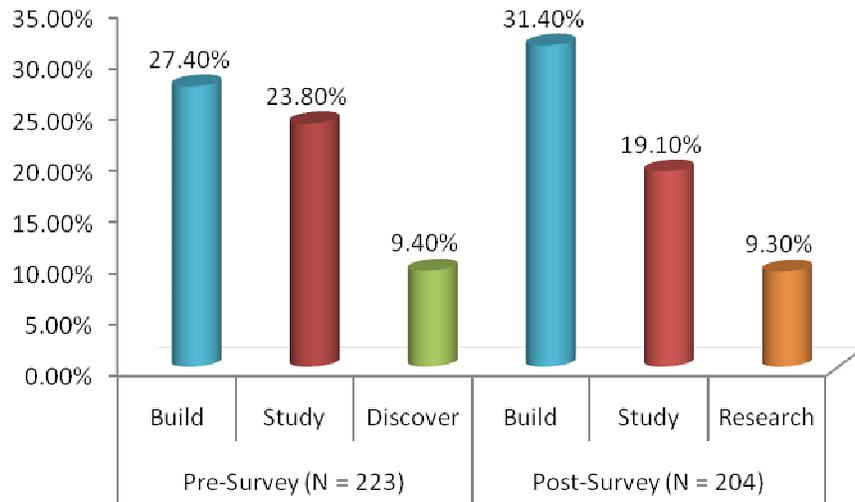


**Figure 4:** Student attitudes towards engineering, science, and math (Pre-Survey N = 223, Post-Survey N = 204)

### *Characteristics of Engineers*

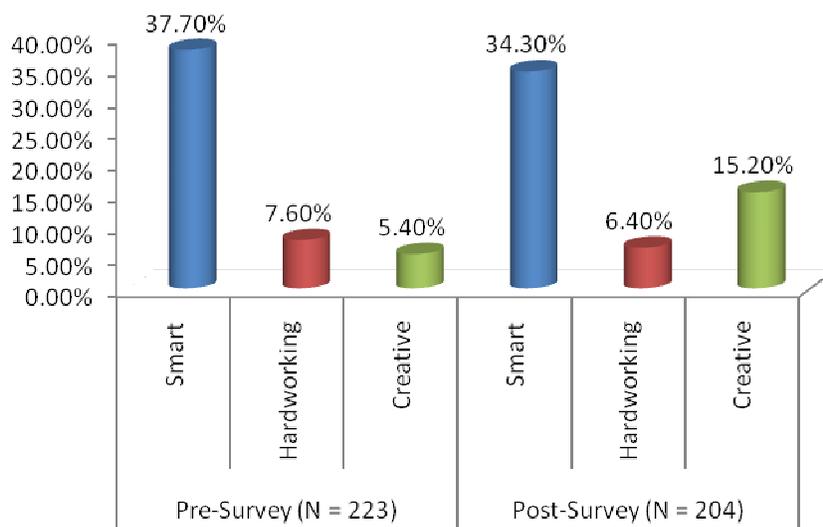
The survey also asked students to list some of the things that engineers and scientists do. Figure 5 shows the top three answers on the pre and post surveys. It was encouraging to see that at the end of the year students were more interested in what an engineer does than what it takes to be an engineer (“Build” increased from 27% to 31% while “Study” decreased from 24% to 19%).

Also, while “Discovered” became the fourth highest ranked answer in the post-survey, the emergence of “Research” as a popular description shows the influence the fellows had on exposing the students to research and graduate school.



**Figure 5:** Most common responses to, “Can you list some of the things an engineer or scientists does?”

Figure 6 presents the pre and post survey results for the three most popular answers to the question “Use three words to describe and engineer or scientist.” It was again encouraging that students were less focused on the amount of work that an engineer/scientist does and more focused on the creativity of engineers and scientists.



**Figure 6:** Most common responses to, “Use three words to describe an engineer or scientist.”

## Conclusions and Future Work

Since 2008, the IMPACT LA Program has been building an infrastructure to strengthen the engineering and science pipeline for K-20 students. Our infrastructure includes strong partnerships with partner schools and minority engineering programs, a comprehensive training program, a fun summer camp and planned open house for community outreach, and a strong assessment team and metrics.

We are continually looking for ways to strengthen the infrastructure of the IMPACT LA Program. While the program has some strong ties with industry, we plan to expand these to create a database of industry sponsors and STEM role models. One such Hispanic role model, Mars Mission Manager Alfonso Herrera, led teachers and fellows on an awe-inspiring tour of JPL to kick-off our program. To strengthen the pipeline to the PhD, we will continue to build partnerships with PhD granting institutions. To improve our training program and start laying the groundwork for sustainability, we will create a new course that takes the best of our Tech 494 course on lesson planning and curriculum development and combines it with research and time management skills training, awareness of STEM research opportunities and careers, and a service learning component to engage other CSULA undergraduate and graduate students not funded through the IMPACT LA program. We will continue to work with Great Minds in STEM to look for ways to outreach to the community. Lastly, we will continually improve our assessment metrics based on program feedback. For example, to get a better understanding of how we are changing the perceptions of Hispanic girls, we will ask for gender information on surveys.

## Acknowledgement

This work is sponsored by NSF Grant #0742426.

## Bibliography

[1] *Changing the Conversation: Messages for Improving Public Understanding of Engineering*. National Academy of Engineering. Washington, D.C., National Academies Press, 2008.

[2] L. Davis and R. Gibbin, at el. *Raising Public Awareness of Engineering*, Washington, D.C., The National Academies Press, 2002.

[3] L.C. McAfee and D.L. Ferguson. "Work in Progress: Status and Experiences of Minority Doctoral Students in Science, Technology, Engineering, and Mathematics Disciplines," in Proc. 36th ASEE/IEEE Frontiers in Education Conference, 2006.

- [4] L. Oseguera, A. Locks, and I. Vega. "Increasing Latina/o Students Baccalaureate Degree Attainment: A Focus on Retention." *Journal of Hispanic Higher Education*, vol 8, no 1. January 2009
- [5] M. T. V. Taningco. "Latinos in STEM Professions: Understanding Challenges and Opportunities for Next Steps. A Qualitative Study Using Stakeholder Interviews," Tomas Rivera Policy Institute. April 2008.
- [6] S. Caonguyen and R. Vellanoweth. "Locating the Lipid Transfer Protein (LTP) Network for Developmental Regulation in Flowering Plants" SACNAS National Conference - Improving the Human Condition: Challenges for Interdisciplinary Science, October 2009.
- [7] M. Zhang and D. Won. "Information in Pooled and Labeled-Line Spike and Spike Trains in Velocity-Encoding Generalized Linear Model," Biomedical Engineering Society (BMES) Conference, October 2009.
- [8] N. Zohrabyan and J. Dong. "Content Adaptive Error Concealment for Packetized Zero-tree Wavelet Coded Images over Lossy Networks," The 2009 International Conference on Image Processing, Computer Vision, and Pattern Recognition (ICCV'09), July 2009.
- [9] J. Castellanos and A.M. Gloria, M. Kamimura. (2006, Eds.). *The Latina/o Pathway to the Ph.D.: Abriendo caminos*. Sterling, VA, Stylus.
- [10] G.E. Slaughter. "The Richmond Area Program for Minorities in Engineering: Summer Engineering Institute," in Proc. of 38th ASEE/IEEE Annual Frontiers in Education Conference, 2008.
- [11] *IMPACT LA Nudges Children Toward STEM*. California State University, Los Angeles Spotlight Article, 2009. <http://www.calstatela.edu/univ/ppa/spotlight/archive/2009/impact-la2.php>.