9-2008

Undergraduate Research: A Bridge to Graduate Education in Agricultural Biotechnology for Hispanics

Eliezer S. Louzada

Hilda Sonia de Rio

Allison J. Abell

Gerson Peltz

Michael W. Persans
The University of Texas Rio Grande Valley

Teaching Methods

Undergraduate Research: A Bridge to Graduate Education in Agricultural Biotechnology for Hispanics

Eliezer S. Louzada[1,4], Hilda Sonia de Rio[1], Allison J. Abell[2], Gerson Peltz[2], and Michael W. Persans[3]

Additional index words. **Internships, molecular biology, experiential learning, hand-on, agricultural science**

Summary. **Hispanics lag behind all other U.S. ethnic groups in education, and are especially poorly represented in science careers. Undergraduate research is an efficient method to attract undergraduate students to science, and many universities are taking advantage of this; however, much still needs to be done to fully explore its potential. In 2000, Texas A&M University-Kingsville, in collaboration with the University of Texas at Brownsville and the University of Texas Pan-American, initiated a undergraduate research internship program in citrus biotechnology to channel Hispanic undergraduate students into graduate education. To date, 51 internships have been provided, and 20 students have been channeled into graduate school, including four at the doctoral level. Most were first-generation college students.**

For many decades, The United States has been the world leader in the sciences, but it is currently experiencing shortages of trained science workers, and this has allowed other countries to challenge its economic strength and leadership in science (George et al., 2001). This shortage is currently being filled by foreign guest workers, which is a short-term solution but does not fully solve the problem. Given the recent regulations governing foreign researchers and their ability to work in the United States, a new pool of scientists must be recruited from domestic sources to fill this labor gap. Hispanic Americans and other minority groups represent an untapped reservoir of talent that could be used to fill this shortage in science, if proper funds are applied to train these promising domestic graduate students. The American Council of Education (2003) reported that in the 2 years after the 2000 Census, Hispanics accounted for half of the country's population growth, reaching the growth predicted for 2014 and are officially the nation's largest minority group. It is projected that by 2030, one in four Americans will be Hispanic (Day, 1996).

Hispanics are behind the white population in all educational levels. In 2005, from all U.S. high school graduates 18 years old and older, only 11.32% were Hispanic compared with 71.25% for white non-Hispanics. In the same year, 80.67% of all people 25 years old and older graduating with masters' degrees were white non-Hispanics and only 4% were Hispanic. Also in 2005, a survey of all doctoral degrees conferred in the country indicated that only 4% were granted to Hispanics compared with 79% of white non-Hispanics (National Center for Education Statistics, 2005). The rapid population growth of Hispanics, together with their low educational attainment, represents a challenge for the United States because its technology-based economy requires a significant pool of highly skilled workers.

Hands-on experimentation has been found to be effective in changing students' attitudes toward science (Ornstein, 2006), facilitating the knowledge acquisition process (Maletta et al., 1999). Furthermore, by participating in research, the students develop critical thinking, originality, independent learning, self-confidence (Khelifa et al., 2004), evaluation and communication abilities, time management skills, and interpersonal independence (Bauer, 2001). Above all, hands-on internships give first-hand ideas to students about real world factors that may be encountered in science careers. Students will also strengthen their commitment to continue along a chosen career path, or the research experience will alert them about the need to rethink their choices (Tom, 1999).

By examining the current situation of the Hispanic community as it relates to education, participation in science careers, social economic factors, and the lack of science role models, we can conclude that this minority group would greatly benefit from hands-on internships in sciences at all grade levels.

Texas A&M University–Kingsville Citrus Center (TAMUK-CC) is an off-campus research facility located approximately 110 miles (177.0 km) south of the main campus in Kingsville, Texas, and about 10 miles (16.1 km) from the Mexican border, in an

Special thanks to the U.S. Department of Agriculture-Hispanic-Serving Institutions Education Grants Program (USDA-HSI) for the funding to carry out this project.

[1]Texas A&M University-Kingsville Citrus Center, 312 N. International Blvd., Weslaco, TX 78596.

[2]The University of Texas at Brownsville, Department of Biological Sciences, 1.828 Life and Health Sciences Building, Brownsville, TX 78520.

[3]Department of Biology, The University of Texas Pan-American, 1201 West University Drive, Edinburg, TX 78539.

[4]Corresponding author. E-mail: elouzada@ag.tamu.edu.

area with a population that is more than 90% Hispanics. This distance from the main campus was a hindrance in the past for the recruitment of graduate students. To address the problem, collaboration was established with two local universities, and an undergraduate research program was initiated to channel undergraduate students to graduate school at TAMUK-CC. This article discusses the results obtained during 6 years of undergraduate internship.

Methods

Locations. This undergraduate research program was the result of collaboration between TAMUK-CC, the University of Texas at Brownsville (UTB), and the University of Texas Pan-American (UTPA). UTB was part of the program during the first 3 years and is located approximately 40 miles (64.4 km) from TAMUK-CC. The UTPA collaboration started in the third year of the program and the university is located approximately 20 miles (32.2 km) from TAMUK-CC. The two institutions together serve more than 25,000 students, nearly 90% of whom are Hispanic. The biology departments of both universities combined have over 1500 students majoring in biology or chemistry who were the target student populations of this project.

Participants and procedures. The undergraduate research internship program started in the summer of 2001 and is still operating; however, the data for this article is current up to June 2007. Students were recruited through word of mouth, advertisements in classes, on posting boards, and through the offices of career services of UTB and UTPA. Student selection was based on grade point average (GPA) scores, personal interviews, and on biology, biochemistry, or molecular biology courses taken. The GPAs ranged from 2.4 to 4.0, with a mean of 3.26 and an average of 3.29. More than 95% of the students were biology majors, and the remaining were chemistry majors with a biology minor. Fifty-one undergraduate students from the two University of Texas institutions have participated thus far in the internship program in the TAMUK-CC and UTPA biotechnology laboratories. None of the applicants had previous experience in research. During the spring and fall semesters, the students were on a 19-h per week schedule, and during the summer, they worked 30 h per week. The minimum internship length was 6 months, with several students participating for 1 year or more. Each student received a stipend of $8 per hour to offset the cost of transportation because they lived 20 to 40 miles from TAMUK-CC. The first week was devoted to safety training, pipetting techniques, general equipment use, and an overview of the ongoing research projects. Before the students were linked to any specific project, they went through basic technique training in deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) isolation, reverse transcription-polymerase chain reaction (RT-PCR), and general gene cloning. After the initial training, each student carried out a research project to isolate a known gene, from RNA isolation to cloning the gene, including sending it for sequencing, Basic Local Alignment Search Tool searching the National Center for Biotechnology Information database, and analyzing the sequences to define the open reading frame and untranslated regions. Furthermore, the students isolated the genomic clones and learned how to find the exons and introns. From that point, the students were placed to work directly with a Masters or PhD student taking part in their research project, or engaged in participating with other students in other ongoing research. All projects were related to genes responding to stress in citrus or in genes involved in metal tolerance in bacteria and fungi and associated with roots of metal hyperaccumulating plants. During the internship, the students became more familiarized with the research topics by reviewing papers from the current literature, participation in paper presentation, and informal discussions. The project director maintained weekly contact meetings with each student about problems encountered in their research, troubleshooting, and career opportunities in agricultural biotechnology. After the internship, the students were asked to write a few paragraphs about the general impact of the research training on their lives, including their career choices, decisions and analysis capacity, and career planning. Moreover, the students were closely followed until their graduation, and were advised about enrolling in graduate school. If a graduate assistantship was not available for the students at TAMUK, the project director would arrange placement in other universities where assistantships could be provided.

Funding for the project (about $1.2 million) was obtained from the U.S. Department of Agriculture-Hispanic Serving Institutions Education Grants Program (USDA-HSI). The first funding occurred in 2000, with the internships starting in 2001. About 50% of the amount was for student internships, five graduate student assistantships (Master of Science degree), and for one research associate (2 years). About 15% was used for supplies, 8% for equipment, and 8% for time release for one faculty. There was no additional faculty incentive, and two faculty and one staff technician (not supported by the grant) were responsible for mentoring the students. Students participating longer than a one-semester internship were trained as mentors. Participation in the internship for longer than one semester was based on the need for trained personnel for a specific project, the quality of the student, and the availability of funds.

Results and discussion

Impact of the undergraduate research. The undergraduate research internship was funded in 2000 and started in Summer 2001. Eighteen undergraduate students from UTB and 33 from UTPA participated in the project through June 2007. Most of the students were juniors and seniors. The reaction of all the students was similar during the first 2 weeks of the internship: they showed hesitation to participate and to even touch instrumentation in the laboratory. After passing through the training process, the students developed the confidence to carry out a semi-independent project involving the isolation and characterization of a known gene. During this time, the general feedback from the students was that what they learned in related classes became more comprehensive, and they discovered that they had abilities that they were unaware of regarding their competence in the research laboratory. None of the

students had science as a career choice before the internship; however, afterward, many decided to pursue careers in science. Thus far, 20 students have entered graduate schools, most in molecular biology-related fields, including four at the doctoral level in molecular environmental science. Thirteen of the students joined the graduate program at TAMUK-CC, four at UTPA, and two at UTB. Additionally, two students have recently applied for the masters' degree program at TAMUK-CC and three for the doctoral degrees at Texas A&M University in College Station (TAMU) for 2008. From the four doctorate students, three are at TAMU and one is in Zurich, Switzerland (from BS directly to PhD). TAMUK does not offer a PhD in molecular biology. Some of the areas of study were genes upregulated by abiotic and biotic stress, expression of metal-tolerant proteins in yeast, metal-tolerant bacteria and fungi that are associated with the soil and root system of metal hyperaccumulating plants, molecular fingerprinting of mites and insects, etc.

The impact of the internship can be seen in every student who went through the program. One undergraduate student who initiated the internship when he was barely a sophomore has been working in our laboratory for 2 and 1/2 years. During this time, he also attended a summer internship in the Department of Plant Pathology and Microbiology at TAMU. The following is a quote from his TAMU faculty advisor, Dr. Paul de Figueiredo, regarding his performance in the summer internship (the students' name is omitted): "The student not only exceeded my very high expectations for intellectual and experimental rigor, but also, favorably impressed departmental faculty and graduate students. He demonstrated a solid understanding of basic concepts in molecular and cell biology, and independently obtained information about topics that were less familiar to him. He also proved to be both an independent thinker and experimentalist. In short, the student displayed skills that are often found in an excellent graduate student." When this student initiated his internship as a sophomore, he did not have any research experience in a research laboratory.

From the feedback letters received from the undergraduate interns after completion of the internship, the following summarizes their feelings:

They had never been exposed to molecular biology work beyond laboratory classes; therefore, they felt intimidated and unqualified to apply for the internship.

In the beginning of the internship, they were frightened by all the new information, equipment, and techniques. As the internship proceeded, they became excited about the molecular biology field as a career choice.

They found themselves as leaders in their laboratory classes and could better understand their upper level classes.

The internship elevated their self expectation and self confidence, and they discovered new abilities that they did not realize they had. This allowed them to redirect their goals and find guidance and directions to change their career choices.

CRITICAL EVALUATION OF THE UNDERGRADUATE RESEARCH PROGRAM. During the 6 years of undergraduate research internships, we have served 51 students, 33 women and 18 men. Five students did not take the internship seriously, finding reasons to be absent or not following directions; one of them quit in 2 weeks without any notice, two were ended early, and two others completed the internship. Eleven undergraduate students were premedical biology majors and most of them performed very well in the laboratory, were very responsible, and stated clearly that their view of agricultural science careers changed completely after the internship. However, none of them changed their career choice. Three students became science teachers after their BS graduation and two after the MS degree. Ten students are still to complete their BS degrees and some are interested in graduate education. Twenty students joined graduate school at the master level during the 6 years, 10 of whom have already graduated. Four of them are at the doctoral level in the molecular field, two are high school science teachers, and four are professionals in their area of expertise. Two undergraduate students recently applied for the graduate program at TAMUK. Additionally, one undergraduate student and two masters students have applied for the plant pathology doctoral program at TAMU for 2008. One PhD student is about to graduate and has already applied for an assistant professor position in the United States. Three out of the four doctorate students are Hispanic and first-generation college graduates. The five students who recently applied to graduate school for 2008, MS or PhD, are all Hispanics and four are first-generation college graduates. There was no influence of duration of internship in the students' choice to continue their education because most of the students going to graduate school had a normal internship duration, mainly because of funding limitation.

We consider the program a success because it changed the lives of many students, and several are heading toward science careers. We have no problem currently in attracting local students to our graduate program, which was very difficult before the establishment of this undergraduate research, because of our distance from the TAMUK or TAMU main campuses. We believe that a similar setting would be a success in other places regardless of ethnic group of the students. Two faculty and one technician were directly involved as mentors and none of the faculty are Spanish speaking, therefore, it is very unlikely that the faculty ethnic background influenced the students' decision or perception about the program. The technician is Hispanic. However, more than the ethnic background, we believe that it was her patience and dedication that had great influence on the students.

We believe that the most important factors for the results obtained were that all the students were treated as potential scientists and we became their models for career choices. The students were deeply involved in the life of the laboratory, including being responsible for ordering reagents and consumables that were part of their research. They were encouraged and expected to participate in technical aspects and troubleshooting of ongoing research. Mistakes were taken as opportunities to learn, and not as failures. Students with more experience were expected to mentor incoming students, which facilitated the adaptation of the new students

into the program, creating a friendlier atmosphere and developing self-confidence in both levels of students.

Comparing the student attitudes in the laboratory before and after the internships, in addition to interviews with the students, we observed that the students developed very strong critical thinking, improved decision making, enhanced analytical abilities, and increased self-confidence. A common comment made by the students was that they felt that their personal lives changed for the better.

Supporting our observations, Sales et al. (2006) reported that undergraduate research was very effective in improving students' knowledge of their hidden science-related skills and their critical thinking. Moreover, they found that the presence of graduate students and postdoctoral scientists as mentors was critical for the success of their program because they became academic models for the undergraduate students. Houlden et al. (2004) observed that pre-medical undergraduate students participating in an elective research class developed an interest in pursuing research careers in addition to developing critical appraisal, information literacy, and critical thinking. Additional outcomes reported for undergraduate research experiences are initiative, self-discipline, confidence, integrity, perseverance, passion (Banta, 2004), technical, team, communication and problem solving skills (Teller and Gates, 2001).

From the faculty standpoint, we observed that undergraduate research produced a potential group of excellent, well-trained undergraduate students that in many cases are at a technical level equal to advanced master degree students and are able to start their doctoral program after finishing their Bachelors. Therefore, the time spent training the undergraduate student is beneficial to faculty and students. We are currently attempting to obtain additional funding to expand the program to include other disciplines in addition to molecular biology. More information about the program can be found online (TAMUK-CC, 2007).

Literature cited

American Council of Education. 2003. New report examines trends in Hispanic students' education. 30 Jan. 2008. <http://www.acenet.edu/AM/Template.cfm?Section=Home&CONTENTID=4226&TEMPLATE=/CM/ContentDisplay.cfm>.

Banta, T.W. 2004. Assessing outcomes of undergraduate research programs. Assess. Update 16:3–16.

Bauer, K.W. 2001. The effect of participation in undergraduate research on critical thinking and reflective judgment. 41st Annu. Mtg. Assn. Inst. Res., Educ. Resources Info. Ctr. Dig. ERIC ED457747.

Day, J.C. 1996. Population projections of the U.S. by age, sex, race, and Hispanic origin: 1995–2050. U.S. Bureau of the Census, Current Population Reports P25–1130.

George, Y.S., D.S. Neale, V. Van Horne, and S.M. Malcom. 2001. In pursuit of a diverse science, technology, engineering, and mathematics workforce: Recommended research priorities to enhance participation of underrepresented minorities. Amer. Assn. Advancement Sci., Natl. Sci. Foundation Grant No. HRD-9817536, A002, 20 Mar. 2007. <http://ehrweb.aaas.org/mge/Reports/Report1/AGEP/index.htm>.

Houlden, R.L., J.B. Raja, C.P. Collier, A.F. Clark, and J.M. Waugh. 2004. Medical students' perceptions of an undergraduate research elective. Med. Teach. 26:659–661.

Khelifa, M., N. Sonleitner, D. Wooldridge, and G. Mayers. 2004. Integrating research into an undergraduate family science program. J. Family Consumer Sci. 96:70–71.

Maletta, M., B.H. Anderson, and J.P. Angelini. 1999. Experiences, instruction and knowledge acquisition: A study in taxation. J. Account. Educ. 17:351–366.

National Center for Education Statistics. 2005. Digest of education statistics. Institute of Education Sciences, U.S. Department of Education. 19 Mar. 2007. <http://nces.ed.gov/programs/digest/d05/ch_1.asp>.

Ornstein, A. 2006. The frequency of hands-on experimentation and student attitudes towards science: A statistically significant relation. J. Sci. Educ. Technol. 15:285–297.

Sales, J., D. Comeau, K. Liddle, N. Khanna, L. Perrone, K. Palmer, and L. David. 2006. Bridging the gap. A research-based approach for teaching interdisciplinary science to undergraduate freshman students. J. Coll. Sci. Teach. 34:36–41.

Teller, P.J. and A.Q. Gates. 2001. Using the affinity research group model to involve undergraduate students in computer science research. J. Eng. Educ. 90:549–555.

Texas A&M University-Kingsville Citrus Center. 2007. Undergraduate internships. 29 Jan. 2008. <http://biotech.tamuk.edu/undergraduate.php>.

Tom, W. 1999. Internships link academic and actual. Fire Eng. 152:159.