AC 2011-2414: UW GENOM PROJECT: A SUCCESSFUL UNDERGRADUATE RESEARCH PROGRAM

Allison Kang, University of Washington

Allison Kang has a background in Biochemistry and Public Health Genetics and is currently finishing up her PhD in Science Education. Her dissertation research focuses on the impact that undergraduate research programs (URPs) have on ethnic minority students’ scientific efficacy and how the programmatic elements of URPs impact student interest and experience in science and engineering.
UW GenOM Project: A Successful Undergraduate Research Program for Science and Engineering Undergraduates

If current trends continue, the percentage of whites in the United States by 2020 will decline to 63.7% (down from 75.6% in 2000) and by 2050, almost half of the U.S. population will be nonwhite. The group predicted to make up the majority of the nonwhite population are Hispanics, but other underrepresented minority groups will also grow substantially. Hispanics make up roughly one in every five high-school-age youth, compared with one in ten in 1990. Those trends are expected to be reflected in the state of Washington as well, but Washington also has a relatively large population of Alaska Indians/American Natives (AI/AN), about 1.6% of the population. Combined with Oregon and Idaho, the Northwest is home to approximately 170,000 (6.8%) of the nation’s federally-enrolled tribal members.

African Americans, Hispanics and Alaska Indians/American Natives (AI/AN) together only account for 11.3% of the science, engineering, technology and math (STEM) workforce outside of universities, but make up 29% of the population. From 2000-2020, the non-Hispanic labor force will grow by 9%, while the Hispanic labor force will grow by 77%. Tremendous disparity still exists in the educational achievements of adults from different ethnic groups (Table 1), suggesting that the changing demographics will create a significant workforce problem in STEM fields in the future. For example, over 41% of Hispanic students never graduate from high school, as compared to less than 10% for White students, and Asian students earn PhDs at nearly five times the rate of African Americans (5.9% vs. 1.2%).

Table 1. Percentage of U.S. adults ages 25 and older by educational achievement* (2005)

<table>
<thead>
<tr>
<th></th>
<th>Did not finish HS</th>
<th>HS/GED</th>
<th>Some college</th>
<th>AA/AS</th>
<th>BA/BS</th>
<th>MA/MS</th>
<th>MD or PhD</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>9.9</td>
<td>32.9</td>
<td>17.4</td>
<td>9.3</td>
<td>19.7</td>
<td>7.7</td>
<td>3.1</td>
</tr>
<tr>
<td>Asian/PI</td>
<td>12.3</td>
<td>20.9</td>
<td>11.0</td>
<td>6.6</td>
<td>31.8</td>
<td>11.5</td>
<td>5.9</td>
</tr>
<tr>
<td>URM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>18.5</td>
<td>37.3</td>
<td>18.5</td>
<td>8.0</td>
<td>12.5</td>
<td>4.0</td>
<td>1.2</td>
</tr>
<tr>
<td>Hispanic</td>
<td>41.5</td>
<td>27.6</td>
<td>13.3</td>
<td>5.6</td>
<td>8.5</td>
<td>2.4</td>
<td>1.1</td>
</tr>
<tr>
<td>AI/AN</td>
<td>24.2</td>
<td>31.6</td>
<td>19.2</td>
<td>10.6</td>
<td>10.3</td>
<td>2.6</td>
<td>1.6</td>
</tr>
</tbody>
</table>

*Includes private/public 4-year and 2-year universities, colleges, and MSIs.

The current educational system also does not adequately serve students from low socio-economic status (SES) backgrounds, and innovative steps are needed to both modify the educational system and increase access and success rates for underserved students. The college pathway is a complex one, with families’ cultural, social, academic and economic backgrounds all playing key roles that impact students’ future careers in life science.

In 2004, 62% of high school seniors from the highest SES quartile enrolled in a science course, compared to 48% of the seniors from lowest SES quartile. Only 21% of low-SES high school seniors will apply to college, as compared to 76% of high-SES seniors, and race/ethnic background is significantly correlated with SES status (Table 2).
Table 2. Percentage of U.S. high school seniors by SES quartiles, 2004

<table>
<thead>
<tr>
<th>SES Quartile</th>
<th>Lowest</th>
<th>Middle Two</th>
<th>Highest</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>16.4</td>
<td>52.7</td>
<td>30.9</td>
</tr>
<tr>
<td>Asian</td>
<td>27.5</td>
<td>41.6</td>
<td>30.9</td>
</tr>
<tr>
<td>Multiracial</td>
<td>26.1</td>
<td>52.7</td>
<td>21.2</td>
</tr>
<tr>
<td>Black</td>
<td>37.1</td>
<td>49.4</td>
<td>13.5</td>
</tr>
<tr>
<td>Hispanic</td>
<td>50.5</td>
<td>39.4</td>
<td>10.1</td>
</tr>
</tbody>
</table>

In 2000, Hispanics comprised 10% of post-secondary students in the US; they made up 14% of students at 2-year colleges but only 7% of the population at 4-year colleges. At our university, out of the 42,094 students enrolled in Fall 2009, 3.1% were African American, 5.1% were Hispanic, and 1.2% were AI/AN.

Abed has shown that English language learners (ELLs) do not perform as well on tests that include complex language, even in subject matters that are not specifically focusing on the English language. In addition, at the high school level, few ELLs take courses that will prepare them for a STEM curriculum in college. In her study of ELLs in northern California, Callahan found that only 10% of 10th-12th grade ELL students had completed both geometry and Integrated Lab Science 2. Students whose parents never attended college are also at a great disadvantage in the college education process; they can rarely turn to their parents for advice about the college application or survival process. Often their families rely more on teachers to provide college guidance, assuming that educators will have the most relevant knowledge and experience. The parents’ own lack of education inhibits them from serving as advocates for their children. The mother’s educational level is particularly relevant since her achievement predicts persistence of a student better than the education of the father, or of the parents together. First-generation status places an additional burden on students from low socioeconomic (SES) groups: only 23% of low-SES students have parents with college experience, as compared to 99.3% for high-SES students. Many students struggle to find a balance between the financial cost of college versus finding work immediately to assist their families.

Minority students are underrepresented in STEM fields for a multitude of reasons, one of them being a lack of high-quality mathematics and science education in high school. Most URM students attend high schools with poorly qualified instructors, minimal computer equipment, and few or no Advanced Placement courses. In addition, URM students are more likely to be placed in non college-track courses early on, limiting their academic choices. Many URM students are assigned to lower curriculum levels, independent of their test scores; this is particularly true for math courses. Approximately 1/3 of URM students intend to major in science and engineering as college freshmen; however, of that group only 37% graduate in a STEM field. Of the more than 60,000 B.S. degrees earned in biological sciences in 2004, fewer than 15% went to URM students (Table 3). In comparison, the retention rate for majority students in STEM is 68.3%. African American and Hispanic students are also more likely to drop out of college altogether because of finances, poor precollege preparation, low faculty expectations, poor teaching, and inflexible curricula.
Table 3. Undergraduate Enrollment and Degrees Earned\textsuperscript{7, 22, 23}

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>14,424,448</td>
<td>650,768</td>
<td>1,354,710</td>
<td>62,253 (4.59%)</td>
</tr>
<tr>
<td>African Amer</td>
<td>1,716,696</td>
<td>81,183</td>
<td>131,241</td>
<td>4,997 (3.80%)</td>
</tr>
<tr>
<td>Hispanic Amer</td>
<td>1,656,529</td>
<td>72,270</td>
<td>94,644</td>
<td>4,454 (4.70%)</td>
</tr>
<tr>
<td>AI/AN</td>
<td>143,024</td>
<td>8,119</td>
<td>10,638</td>
<td>402 (3.77%)</td>
</tr>
</tbody>
</table>

*Includes private/public 4-year and 2-year universities, colleges, and MSIs.

Extrapolating from the 1998 data on undergraduate degrees earned\textsuperscript{4}, \(~7\%\) of all students earning BS degrees in biological sciences went on to earn their PhDs. For African Americans, the rate is \(~3\%\), for Hispanics, the rate is \(~5\%\), and for AI/ANs, the rate is \(~1.5\%\). These numbers have a significant impact on the ability of our nation’s research force to address the complex issues of health disparities\textsuperscript{24}.

In the rapidly growing field of genomics, the situation is even more dire. For example, in 2006, of the 2,154 graduate students in the US studying genetics, only 11 were Native American (2 were GenOM Fellows at our university and have since earned their PhDs in Genome Science), 66 were African American, and 62 were Hispanic\textsuperscript{25}. Table 4 illustrates the numbers and percentages of PhDs awarded to URMs in biology relative to all other science/engineering PhDs.

Table 4. PhD degrees awarded, 2006\textsuperscript{26}

<table>
<thead>
<tr>
<th></th>
<th>All science/engineering</th>
<th>Biological Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>URM</td>
<td>6.67%</td>
<td>6.29%</td>
</tr>
<tr>
<td>Black</td>
<td>964</td>
<td>173</td>
</tr>
<tr>
<td>Hispanic</td>
<td>1071</td>
<td>226</td>
</tr>
<tr>
<td>AI/AN</td>
<td>105</td>
<td>23</td>
</tr>
<tr>
<td>Non-URM</td>
<td>93.33%</td>
<td>93.71%</td>
</tr>
<tr>
<td>Temp Res</td>
<td>12993</td>
<td>1990</td>
</tr>
<tr>
<td>Unknown</td>
<td>1501</td>
<td>302</td>
</tr>
<tr>
<td>Asian/PI</td>
<td>1465</td>
<td>563</td>
</tr>
<tr>
<td>White</td>
<td>13981</td>
<td>3426</td>
</tr>
</tbody>
</table>

In addition to the challenges mentioned above, many URM citizens have concerns about the ethical, legal, and social implications (ELSI) of genome sciences as they apply to minority communities\textsuperscript{27-37}. In order for many of these social issues to be addressed, it is critical that more people of color enter the field of genome sciences to bring their unique perspectives into this field. Conducting research in ethnic communities is more effective when there are scientists of color who are advocating for those communities. These social factors combined with under-representation make it critical to take progressive and innovative steps to increase the number of minority students entering and succeeding in genome sciences careers.
In order for underserved students to become a vital part of the STEM workforce, it is necessary for them to do more than simply graduate with a college degree. To solve our looming workforce issue, a significant number of these students must go beyond the minimum, and truly excel. Undergraduate research experience by itself is not the only important factor to move students from simple retention in the life sciences to extraordinary achievement. For many underrepresented minority students, research shows that students must also develop an identity as a scientist, while retaining their core identity as a person of color. As Ong described, students from underserved groups in science "must contend with common effects of low representation, including isolation, doubts associated with tokenism, tenuously balanced social identities, and disproportionate skepticism from others- and themselves-about their qualifications and abilities to succeed in predominantly male and/or white fields." Kahveci et al. illustrate how a program for college women positively influenced the participants’ decision to pursue careers in STEM through activities that provide for cognitive, social, and emotional support. Cognitive support is common in undergraduate programs (laboratory research, tutorials, etc). However, social and emotional support components are typically not as well-developed and are often missing in programs targeting underserved students.

For students to become full members of the community of scientists and engineers, they must also learn to communicate as scientists. One essential skill is learning how to become a critical reader of peer-reviewed journals. A critical reader not only understands the material, but also analyses how the author presents the material. A critical reader will detect the purpose of the author, recognize bias, and be aware of tone/persuasive elements in language and presentation. Brill and Yarden found that high school students who read research articles, as compared to textbooks, increased the complexity and depth of their questions. Training students to read primary research articles also increases their understanding of graphical and statistical presentations of results. Herman found that as students read primary literature they become more comfortable with interpreting data, weighing inconsistent evidence, and developing their own high-quality standards for research. Griffen et al. found students who truly ‘got’ the purpose of a lab manual (interactive notekeeping, recording thoughts, etc.) performed significantly better in writing up their results in a research paper at the end of the experience, replicating how scientists actually write papers. These researchers also found that students showed a significant improvement in their understanding when their laboratory notebooks were interactive.

Another challenge that the undergraduate programs has had to address as the population of students shifted in the last several years has to do with technology in learning. Prensky termed this new generation of students “digital natives”; students who have been born into and immersed in digital technology such as emails, blogs, cell phones, Facebook, and the internet and where these sources are their primary sources of communication and learning for these students. For those who have acquired this digital experience as adults (“digital immigrants”), this kind of communication style is unconventional. Digital natives have a different approach to learning, frequently mistaking the quick gathering of facts as deep knowledge. As a result, there are major implications for teaching and pedagogy. Prensky appeals to educators to become fluent in the use of technological tools that process information and increase “thinking power.” He argues that this allows for wiser decision making. In fact, it can even be possible for
adults who graduated from high school without the ever-present text message, to become digitally native\textsuperscript{50}.

Gándara\textsuperscript{51} has found that successful educational intervention programs for minority students include the following components: (a) intensive monitoring of participants, (b) an articulated program that reaches across grade levels, (c) consistent messages to raise aspirations, (d) building group cohesion and a sense of membership in the school and the program, and (e) access to rigorous curriculum and support to succeed in that curriculum. The UW Genomics Outreach for Minorities (GenOM) Project is an undergraduate research program for underrepresented ethnic minorities that focuses on not only these four components, but also on developing career pathways in science and engineering. This program not only provides educational and research opportunities for underrepresented minority students interested in genetics-related fields, but also gives students opportunities to engage in science discovery, focusing on overcoming barriers (chemistry, mathematics, laboratory skills) for students pursuing science and engineering related fields.

The UW GenOM Project increases access by encouraging underrepresented minority groups to pursue enrollment in graduate programs and careers in science and engineering. The students in the program range from freshmen to graduate students, but the majority of the students begin the program as incoming freshmen and continue with the program through their undergraduate and graduate years. Since the inception of the program in 2002, the UW GenOM Project has been remarkably successful in retaining students in color. For example, 98% of the high school seniors in the incoming freshmen summer program have gone on to college, and over 93% of all the undergraduate research participants are retained in science, engineering, and public health.

The goal of the program is to increase the number of minority students at the university who are likely to work in genomics and engineering fields, producing underrepresented minority bachelor’s degree students in these fields. These undergraduates are strongly encouraged to pursue graduate school training in their fields and have been exposed to advanced technologies that are at the interface between genomic science, proteomics, engineering, and nanotechnology. GenOM is based on the principles of recruiting excellent students, building skills, community, self-confidence, and engaging these students in visualizing themselves in a science and engineering career. We use a tiered mentoring system in which students mentor more junior students as they themselves advance along the career pathway. The pathway includes:

- Intensive residential summer program for incoming college freshmen
- Undergraduate research experiences, focused advising/counseling, career development, training in science literacy and laboratory techniques, and sponsored travel to national science conferences.
- Retaining graduate students in science and engineering through recruitment efforts with academic departments and training grants, mentoring opportunities, community development and outreach, mentoring, career advising, peer science talks and sponsored travel to national science conferences.

\begin{figure}
\centering
\begin{tikzpicture}
\node[draw] (incoming) {Incoming Freshmen: Summer Residential Undergraduate Research Experience};
\node[draw, right of=incoming, xshift=2cm] (undergraduates) {Undergraduates: Research, Advising, Training in S&E, Sponsored Travel};
\node[draw, right of=undergraduates, xshift=2cm] (graduates) {Graduate Students and Postdocs: Training grants, Mentoring, Advising, Sponsored Travel};
\draw[->] (incoming) -- (undergraduates);
\draw[->] (undergraduates) -- (graduates);
\end{tikzpicture}
\caption{Pathway through the UW GenOM Project}
\end{figure}
GenOM has grown to serve students at several levels in their educational careers. GenOM currently serves students at three different career levels: 1) Incoming College Freshmen, 2) Undergraduates, and 3) Graduates and Postdocs. The main component of GenOM’s Incoming College Freshmen group is the ALVA summer program. These students enter the University of Washington the summer prior to Fall quarter and build a community of peers and mentors prior to beginning their freshmen year. Through the ALVA summer program students sharpen their scientific literacy skills and become a part of the university’s scientific community early in their undergraduate career.

Undergraduates (including former ALVA students as well as other students at the university who apply to our program) participate in GenOM through undergraduate research, academic enrichment, academic advising, as well as course clustering and graduate school preparation. GenOM also provides undergraduate travel scholarships to encourage students to present their undergraduate research at regional and national conferences. Lastly, Graduates and Postdocs make up the smallest, yet a very substantial part of GenOM’s student population. As GenOM Graduate Student/Postdoctoral Fellows, they serve as tutors, mentors and seminar leaders for our undergraduate students.

**Incoming College Freshmen: The ALVA Summer Program**

ALVA, the Alliance for Learning and Vision for underrepresented Americans, was created by the UW’s Minority Science Engineering Program in 1993, and has been adapted by the UW GenOM Project to include life sciences and genomics. Each year, there are about 14 incoming college freshmen who participate in this 9-week, residential, intensive summer research program. The purpose of ALVA is to increase students’ success in college and address multiple factors that negatively impact minority students’ success in science. These factors include finances, academic preparation, difficulty envisioning themselves as scientists, and lack of community on campus. ALVA is an intensive, hands-on, residential experience that includes chemistry, mathematics and wetlab training, conducting research in a lab, ethics training, and the opportunity to write a science paper, prepare a poster and give an oral presentation.

Students are recruited to ALVA through multiple venues: presentations at high schools and to visiting campus groups, mailings to all MESA schools and teachers, letters to all teachers who have participated in the High School Human Genome Program, all teachers who have written letters of recommendation for students in the past, selected high schools with high minority enrollment, and a special mailing to URM incoming UW freshmen. The UW regularly broadcasts a short video on the UW GenOM Project, titled “Next Generation Scientists: Minority Outreach in Genome Sciences” on UWTV and on their website (http://www.uwtv.org/ctw/). GenOM also had the opportunity to highlight one of its Hispanic students in a televised Spanish-language interview on Univision, which aired primarily in eastern Washington. GenOM staff has recently updated its website (http://depts.washington.edu/genomics/index.shtml), which contains the most updated information from the program, including applications, previous students’ projects, and contact information.

The targeted participants of the program are high school seniors who intend to enroll at the university in the upcoming fall, majoring in life sciences or bioengineering. Specifically,
GenOM is looking for students who are interested in a research career, and are from an underrepresented minority group, and/or are first-generation, low-income, and from rural backgrounds. The most competitive applicants have taken both a math and a science class every year in high school, have maximized their school’s academic resources, have strong grades/test scores, have a compelling personal statement, and strong letters of recommendation. The thorough review of each student’s application includes readings of the file by at least three reviewers, and telephone interviews with ~30 candidates.

Funding for college is a critical barrier for many underrepresented students, both in terms of access and retention\textsuperscript{56,57}. To address this factor, students who participate in ALVA are paid for their summer experience, and their housing and travel expenses are covered. Very few of the ALVA students have to work during their freshman year because of the money they earn over the summer. As a result, their grades are very competitive and they frequently receive scholarships to help support the rest of their college career. The students typically save over $2500 during the summer.

The wetlab training during ALVA gives students the opportunity to learn some basic molecular biology techniques before beginning their undergraduate research experience in the research laboratory. GenOM staff have incorporated best practices and current research about teaching and learning into the wetlab curriculum using inquiry based teaching as a model for instruction\textsuperscript{58,59}. Bybee\textsuperscript{60} states that scientific inquiry is different from simplified scientific method in most schools because inquiry does not proceed in a tidy, linear way. An inquiry-based classroom is where students are “capable of posing their own research questions, determining their own guidelines for evidence, formulating their own explanation from the evidence, linking their explanations to knowledge from external sources and constructing reasonable and logical arguments to communicate explanations”\textsuperscript{60}. During this two-week, intensive, hands-on course, students become more experienced in their understanding of basic molecular biology techniques that are often used in research laboratories. Students learn these concepts and techniques in the safety of their cohort before they launch into their individual research experiences with faculty. While there are many high quality, inquiry-based curricula and supplemental materials in the United States, very few are able to foster the student-scientist networks that Genom has already developed. A significant advantage of this wetlab curriculum is that it prepares students with no lab background for carrying out research in UW laboratories, enhancing the learning experience for students and mentors alike. Many undergraduate students, particularly those of the digital generation, begin their college career with the limited understanding that learning science is only about gathering facts and memorizing information. Therefore, it is important for students to make the intellectual shift towards deeper cognitive skills such as problem-solving and analysis in order to have more in-depth science conceptual understanding\textsuperscript{61}, and be able to succeed in an academic, research-based environment.

Math skills are also vital to a successful science or engineering career, so every ALVA student is placed in a math workshop to prepare them for college calculus. While average mathematics scores have risen for all racial and ethnic groups since 1990, the gap between minority and white students in math still remains, and underrepresented students begin college less prepared for math than their majority peers\textsuperscript{53}. In 2008, only 42.6\% of Hispanic/Latino and 32.6\% of African American high school seniors scored at or above the Proficient level on the Mathematics
Proficiency Exam, while 78.6% of White students scored at this level\textsuperscript{62}. The disparity is even greater at higher levels with 8.1\% of White students scoring at the Advanced level, while only 0.8\% of African Americans and 1.5\% of Hispanic/Latino students achieve the same results\textsuperscript{62}. Much of Treisman’s\textsuperscript{63} research work is incorporated into the design of these math workshops. As other researchers have noted, it is key that these workshops not be remedial\textsuperscript{64}. They are challenging, group-oriented, and since class size is small, there is plenty of room for individual attention. The students take the university’s Math Placement Exam just before ALVA starts; at the end of the summer, students retake the Math Placement Exam and typically rise one course level, and continue to do well in their math courses throughout their college career. The math instructors are typically advanced PhD students in Genome Sciences or Science Education, and/or former ALVA students with very strong math and life science backgrounds.

In response to feedback from students and observations by GenOM staff on the academic challenges faced by incoming freshmen, the GenOM program plans to add a 7-week chemistry workshop to ALVA. The 90-minute chemistry workshops will be offered twice a week. This course will be specifically tailored for the ALVA students, and is designed by the staff at Office of Minority Affairs and Diversity’s Instructional Center (IC) for those who are planning to take the first-year general chemistry series at the university. This course is designed for students with a minimal background in chemistry. During the 7-week course, two IC instructors will focus on these principles and fundamentals of chemistry:

- General Math used in Chemistry
- Atoms, Molecules, and Ions
- Nomenclature
- Stoichiometry & Balancing Chemical Equations
- Intro to Chemical Reactions
- Gases
- Further topics in general chemistry (i.e. chemical equilibrium & acids-bases)

Students will also be trained on how to properly maintain a chemistry laboratory notebook, which includes a Pre-Lab write-up (i.e. Purpose, Procedure, Observations, etc.) as well as a post-lab report write-up (i.e. Data analysis & calculations, Conclusion). The post-lab write-up requires an extensive use of Excel spreadsheets to generate linear plots and statistical analysis (i.e. slope, y-intercept & their standard deviations), which will also be covered during the prep course. Collectively, these activities will not only enhance students’ understanding of the concepts and improve their problem solving skills in chemistry, but it will also teach students how best to study the sciences, integrate concepts, and learn scientific thinking.

Genetics and ethics are both logic-based disciplines uniquely integrated in the day-to-day work of genetic researchers. Given the history of the eugenics movement, it is imperative that ethics is integrated into introductory genetics courses as a core part of a whole rather than an afterthought or add on. It is critical that high school students’ initial genetic research experience involve the development of ethical decision-making skills and abilities to stimulate and reinforce this productive pattern of social/cognitive development. These students are aspiring scholars and researchers of the genetics community and an awareness of ethically appropriate research practices relevant to genetics will enhance their academic preparation, increase student retention
in introductory science courses, and encourage continued interest in larger societal issues. Our inquiry-based teaching modules are drawn from a variety of sources, including curriculum from the NW Association of Biomedical Research and National Human Genome Research Institute’s curriculum. The units, which are integrated with the wetlab curriculum (Table 6), emphasize research ethics, research integrity, and the ethical, legal, and social implications of genetic research, creating an essential and powerful learning experience.

Table 6. Examples of Ethics and Science Topic Pairing

<table>
<thead>
<tr>
<th>Ethics</th>
<th>Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to Ethics in Science, Proper Record Keeping (lab notebooks)</td>
<td>Lab Safety and Pipetting Lab</td>
</tr>
<tr>
<td>The Search for the Structure of DNA (case study)</td>
<td>DNA Structure and Function Tutorial/Lab</td>
</tr>
</tbody>
</table>

These teaching modules, which close with an interactive capstone project, assist the students in making the jump from theory to application while providing an insightful view into the varied science or engineering related career paths. The ALVA ethics capstone project is a proxy for a cumulative final exam that reflects both general and specific learning objectives. At the end of the summer, teacher reflection, review of student assessments and program evaluation demonstrate that the students have an increased awareness of commonly used ethical concepts; the integrated ethos of the ethics in science - mainly genetics research; and in practice applying their newly acquired skill sets.

The ALVA program also gives students the opportunity to work as a scientist or engineering intern in a biotech company or a campus laboratory. As they work, they begin to picture themselves as professionals in this field. Many underrepresented minority students do not see engineering or science as a career for them. Their image of a scientist still remains the crazy white guy in a wrinkled lab coat with unkempt grey hair, holding a burbling beaker. They know few minority engineers or scientists themselves, and know that the minority community at the university is a small one. This new professional, positive self-image that arises from their involvement in the ALVA program helps the students stay focused on their long-term career goals and not get off track when the coursework becomes difficult. Students begin their research work following their two weeks of lab training, so they begin with some preparation and skills. While each research project is different, the majority of students are involved in a small, independent research project under the mentorship of a graduate student/postdoctoral fellow and a faculty member. Frequently, these summer positions lead to ongoing research, as students are often invited by their mentors to continue with their research throughout the academic year.

Weekly lunch seminars give students the opportunity to hear from carefully selected speakers about the variety of research careers connected to genomics. Students are coached to ask questions, and the speakers are encouraged to make the sessions as interactive as possible, encouraging student engagement, and personalizing the talks to their interests.

The summer ALVA students receive intensive training in keeping an accurate laboratory notebook, reading scientific papers, and writing their own research papers. Science literacy requires strong communication skills, both in interpreting others’ work, and explaining and
justifying one’s own. To become skilled scientists, students need to learn how to communicate in this world in which the language and structure may be new to them. With the advent of the Internet, the definition of valid information sources has become fuzzy. Students often do their research online, but do not have the skills or knowledge to determine whether their sources are valid. Many documents are posted on the web without going through the peer review process. Students must learn not only how to conduct searches, but how to validate the accuracy of their sources. Once the students have accurate, original source documents in hand, the next challenge is training them to read and understand these complex articles. This training develops advanced question-asking abilities in the students. Articles are chosen with the current skills of the students in mind, with the goals being to teach students about the nature of scientific reasoning and communication, to learn to critique experimental design, and to relate the findings to the larger world. The students also receive hands-on training and feedback on preparing and writing a 10-page research paper, with an associated full-size poster, and an oral presentation.

Students are housed in dormitories. Particularly for first-generation students, a living/learning environment has been shown to make a significantly positive impact on their transition into college. Paid counselors live with them, building community and assisting the students with coursework and campus/science survival skills. The counselors are very accessible to the ALVA students, and help them adapt to living away from home for the first time, adjusting to life in a large city, and dealing with roommate and minority community issues. Counselors and ALVA staff also lead the students in activities that help them learn about privilege, and its relation to science. It also opens many students’ eyes to the differences and commonalities between each other, leading to more open discussion and tolerance.

On the last day of the summer, students give an oral presentation about their summer work, using a printed poster as a resource. Reflecting on their summer experience and explaining to those outside the field gives students the opportunity to internally incorporate their experience at a deeper level. Katz et al. have found that students who learn in a reflective manner outperform their peers, and have more efficient learning processes. Students receive training and practice prior to their talks, engaging in these reflective processes.

The average retention rate nationwide for underrepresented students interested in science and engineering from the freshman to senior years in college is only 32%. The retention rate for GenOM ALVA students in science/engineering/public health is over 90%, and 98% of the rising high school seniors have gone on to college. This is an exceptional achievement compared to the national average. Table 5 below illustrates the numbers and demographics of the students who applied for the ALVA program for the summer of 2010. This table gives a glimpse of the characteristics of the students who participate in the GenOM program.

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>URM</th>
<th>≤ low-income threshold</th>
<th>Rural environment</th>
<th>1st generation students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applied</td>
<td>194</td>
<td>149</td>
<td>15</td>
<td>18</td>
<td>40</td>
</tr>
<tr>
<td>Interviewed</td>
<td>37</td>
<td>37</td>
<td>8</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>Accepted</td>
<td>16</td>
<td>16</td>
<td>3</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>
The applicant pool for the summer of 2010 was the largest in the history of the program with 194 students applying for 14 positions (2 students declined the offer). A large majority of the applicants, 176 or 90.72%, resided in urban zones; 39 applicants were from out-of-state. About 7.73% of the applicants fell at or below the 2009 low-income thresholds. On average, 20.62% of the applicants for the 2010 program were the first in their family to attend college, while an additional 13.73% would be the first to successfully complete a bachelor’s degree. 77% of the applicants were URMs, illustrating our high levels of success in this recruiting from this population. The race and ethnicity of the applicants is illustrated in Figure 1 below.

![Figure 1: GenOM ALVA 2010 Applicant Race and Ethnicity](image)

The sixteen students selected for ALVA 2010 came from very diverse backgrounds. Three of the students came from out of state and four students from rural areas. Three students fell at or below the low-income threshold and six were first generation college students, with an additional two potentially being the first to obtain a bachelor’s degree. The race and ethnicity of the students was also quite diverse with one student of African descent, two African Americans, two Filipinos, one Native American, one Pacific Islander, eight Hispanic Americans and one student of African American/Asian descent. The demographics of the applicants and participants for ALVA 2010 are illustrated in Figure 2 below.

![Figure 2: GenOM ALVA 2010 Applicant and Participant Demographics](image)
Undergraduate Research (Academic year and Summer quarter)

A significant portion of the UW GenOM project revolves around undergraduate retention and training. Beginning at the freshman level, we have developed a continuum that provides ongoing training, mentorship, and academic assistance for underrepresented students interested in science and engineering. This undergraduate component dovetails with both the ALVA program, and the future graduate efforts, providing a seamless flow of support for these students. At the college level, one way to help students grasp the inquiry process practiced by scientists is for them to work in a science laboratory where “real” scientists do their work. For some undergraduates, this research experience becomes even more critical as they begin to consider graduate school as part of their future careers. Seymour et al. reported from 76 student interviews at four different institutions of higher education that students who had research experiences as undergraduates in science had increased confidence, felt more like a scientist, benefited positively from a mentoring relationship with faculty, and gained a better idea of their future career plans.

It is well known that participation in undergraduate research is a critical experience for many current life scientists. This is one powerful approach to retain students in science, both from the broader population, and from underrepresented minority groups. Students learn that science is an intensely human enterprise comprised of learners and explorers, and they become contributing members of this community. A recent study of underrepresented minority undergraduates enrolled in a successful biomedical support program at UC-Davis indicated that half of their alumni who are now in PhD programs discovered a research career in college. This UC-Davis program included academic support and advising. In a three-year study on the impact of undergraduate research, Seymour et al., noted that 91% of the students had a positive experience. Particular gains included: personal/professional, “thinking and working like a scientist,” laboratory skills, clarification of career plans, enhanced preparation for careers or graduate school, and shifts in their attitudes about learning and working as a researcher. Also, a recent survey of over 1100 undergraduate research participants found that 83% of them were planning to continue on to graduate or professional school in the sciences. Connecting students with faculty mentors in a research lab is a very powerful way to retain students in science. Not
only do they learn that science is a human enterprise, but they also become active members of a “community of learners and explorers.”

The young undergraduate researchers participate in a poster presentation annually at the university’s undergraduate research symposium. The summer undergraduate researchers also participate in a campus-wide summer STEM poster presentation at the end of the summer. All of the students are encouraged to submit their abstracts to national conferences. Once these students have some research experience, the GenOM staff works with the undergraduates and encourage them to apply to summer research programs at other schools. Previous students have participated in programs at universities such as Yale, Harvard, UC Berkeley, and UC Santa Cruz. Of the 98 students who have previously participated in undergraduate research, 61 were female and 37 were male. Significantly, 93 of the students are retained in STEM fields, as Figure 3 below shows.

![Bar chart showing numbers of students participating in the GenOM undergraduate research program, 2003-2010, by ethnicity, and retention in STEM fields.](chart.png)

**Figure 3. Numbers of students participating in the GenOM undergraduate research program, 2003-2010, by ethnicity, and retention in STEM fields.**

Even more significantly, of the 46 students who have earned their bachelor’s degrees after participating in undergraduate research, 43 are in STEM fields. Table 7 below shows where the students have gone after earning their bachelor’s degrees.

<table>
<thead>
<tr>
<th>Graduate school</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning on grad school</td>
<td>9</td>
</tr>
<tr>
<td>In MD/DDS programs</td>
<td>7</td>
</tr>
<tr>
<td>Working in STEM</td>
<td>5</td>
</tr>
<tr>
<td>In MD/PhD programs</td>
<td>3</td>
</tr>
<tr>
<td>Planning on med school</td>
<td>3</td>
</tr>
<tr>
<td>Working in non-STEM</td>
<td>3</td>
</tr>
<tr>
<td>Postbacc (premed)</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 7. Career destinations of UW GenOM Project undergraduate researchers following completion of their bachelor’s degrees.
The grades of underrepresented students in life science courses have risen significantly since the UW GenOM Project first co-funded a biology staff instructor at the Office of Minority Affairs and Diversity’s Instructional Center (IC). The IC is open to all UW students who are from underrepresented minority groups, or are from low socio-economic backgrounds, or are first-generation students. The Instructional Center is home to all of the UW GenOM Project students, as well as their other University of Washington peers. Services offered include: academic support in all life science courses, math, physics, and writing; and workshops on study skills, critical reading, academic achievement, learning styles, and affective behaviors. The staff at the IC does an outstanding job of tracking student usage and success. Each student must swipe their student card on their way in and on their way out of each workshop or class. Grades in the academic classes are measured against the number of times that a student attended a workshop or study session, and how long they stayed.

A key advantage for the UW GenOM Project students is that the director of the IC, and the three life sciences instructors, are all professionals of color. Research has demonstrated that minority student academic achievement increases when they are in a classroom with minority teachers. Villegas, in her thorough review article, gives compelling reasons why teachers of color are particularly effective with minority students: they serve as role models, they have a deeper and personal understanding of their students’ cultural backgrounds, and they improve the academic and social experiences for students of color. What is particularly significant is that the very reasons that Villegas cited for why teachers of color are more effective, are ingrained into the teaching culture at the IC: “(a) having high expectations of students; (b) using culturally relevant teaching; (c) developing caring and trusting relationships with students; (d) confronting issues of racism through teaching; and (e) serving as advocates and cultural brokers.”

Biology workshops at the Instructional Center have focused mainly on the three introductory classes of Biology 180, 200, and 220. The goals of these workshops are to first, provide in a small class environment (15 to 30 students) an additional opportunity for students to hear and understand the major aspects of the previous week’s lecture, secondly to provide an opportunity for students to test their understanding of material by doing study questions in a structured environment, and lastly to give students a chance to ask questions in a comfortable setting. More specifically workshops begin with a half hour to hour lecture covering the week’s material. For example, for Biology 180 the instructor might discuss Darwin’s postulates, natural selection and its effects on population, and Mendelian genetics. Following the lecture, students are provided with study questions and given a specific amount of time to answer them in groups and/or individually. Next the questions are discussed as a group, with the students volunteering their answers and with the instructor guiding them on the best approach to the question (e.g. pointing out clues within the question) and also providing information to students as to what would be a quality answer and how they might adapt their own answer to fit those criteria.

Throughout the workshop students are allowed to ask questions and at multiple times questions and comments are solicited. The goal of the Biology workshop is to help students obtain a deeper level of understanding of the week’s material. The opportunity to do and discuss study questions is integral toward getting students to the level of application of concepts and the synthesis of new ideas based on those concepts. Since the first year series Biology (BIOL 180/200/220) and the first quarter genetics course (Genome Sciences 371) are the most problematic for underrepresented students pursuing careers in life sciences, our goal is that the
grades of URM students in life science courses will meet or exceed the grades of their majority peers.

Skilled advising is essential to student success. The GenOM staff are very knowledgeable about courses at the university, academic enrichment resources, personal counseling services, career development, and graduate school preparation. Through their many combined years working with URM students in STEM fields, the staff have connections with other universities, summer research programs, post-baccalaureate programs, and fellowship/scholarship resources. Travel scholarships of up to $500 are available to send undergraduate students to science conferences to both present their research work and investigate postbaccalaureate and graduate program opportunities. GenOM staff also work intensively with the students on developing their identity as scientists, and managing personal challenges such as racism/sexism, first-generation issues, family dynamics, finances, and increasing self-confidence.

GenOM staff also work with students to coordinate their course schedules, particularly freshmen and sophomores. Clustering students in key classes reduces isolation and facilitates scheduling of study groups and workshops. It also enhances the continuation of peer-community development. The relevant departments (Math, Physics, Biology, Chemistry), and the Minority Science Engineering Program all partner with GenOM in this activity. GenOM connects students with existing campus resources for no- or low-cost GRE preparation courses (i.e., the McNair Program, and the Instructional Center). They also plant the seed of graduate school very early on with their incoming freshmen, encouraging them to consider a research career, and instilling in them the confidence that they are capable of achieving this goal. By their junior year, students are encouraged to look at summer research opportunities hosted at schools they are considering for graduate school. The program staff also talk with students about how to develop relationships with faculty that will lead to strong letters of recommendation, help them selecting graduate schools for application, and with their graduate school application essays.

I participated in the Annual Biomedical Research Conference for Minority Students. I was given the honor of orally presenting my research project, an honor given to only the top six researchers in each discipline. This would not have been possible if I had not participated in the GenOM Project. The GenOM Project truly allows aspiring students to develop their great potential in research. I sincerely believe that I would not be working in science if the UW GenOM Project had not sparked an interest in science and set me on my career path. – UW Alum, ALVA and undergraduate research participant, travel scholarship recipient, now a PhD student in Biochemistry and Biophysics

Graduates and Postdocs

At the graduate level, the UW GenOM Project works very closely with academic departments that conduct research in genome sciences, most particularly, the Genome Sciences department and the Institute for Public Health Genetics. The focus of the program is to support underrepresented minority graduate students and postdoctoral fellows studying genome sciences at several levels: financially, socially, and professionally.

For the first nine years of the program, GenOM has offered one incoming graduate student a two-year award of $5000/year above and beyond their RA/TA support. 22 students have been
involved as sponsored GenOM Fellows, as mentors or volunteers. Ten of the 22 are male, 12 are female. Figure 4 below shows the demographics and current status of GenOM’s previous graduate participants.

![Figure 4](image-url)

**Figure 4.** Demographics of previous UW GenOM Project graduate participants

**GenOM Graduate Student/Postdoctoral Fellows**

Many graduate students and postdocs have served as mentors to undergraduate research students. In fact, they comprise the majority of the mentoring population for students conducting undergraduate research. New research shows that graduate students/postdocs themselves gain a great deal when they serve as mentors to undergraduates. Dolan and Johnson state that "graduate/postdoctoral mentors experienced a wide range of gains, including improved qualifications and career preparation, cognitive and socioemotional growth, improved teaching and communication skills, and greater enjoyment of their own apprenticeship experience. Notably, graduate/postdoctoral mentors reported twice as many gains as challenges, neither of which were limited by their motives for mentoring. Indeed, their motives were fairly narrow and immediate, focusing on how mentoring would serve as a means to an end, while the gains and challenges they reported indicated a longer-term vision of how mentoring influenced their personal, cognitive, and professional growth."

In conjunction with SACNAS (Society for Advancement of Chicanos and Native Americans in Sciences) and GO-MAP (Graduate Opportunities Minority Achievement Program), GenOM has plans on hosting monthly dinner meetings for our graduate students. These dinner meetings would be alternately hosted by SACNAS/GenOM and GO-MAP. Facilitated by a GenOM Graduate Fellow or Postdoc, they will be more opportunities for students to get feedback on their draft science talks from a friendly, constructively critical audience of their peers.

GenOM also has plans on conducting workshops for the parents of high school students who will be the first of their families to go to college. These workshops will be offered in both English.
and Spanish, and will be conducted in the Puget Sound area, and in eastern Washington, where a significant number of Hispanic families reside. The five counties with the highest percentage of Hispanic population (see Figure 5) will be targeted (Adams, 54.1%, Chelan, 25.1%, Franklin, 59.3%, Grant, 36.6%, and Yakima, 42.5%) 89.

![Figure 5. Map of Washington state, showing demographics of the Hispanic population by county, modified from the 2009-2010 Washington State Hispanic/Latino Assessment Report](image)

GenOM expects the numbers of graduate students/postdoctoral fellows involved in service activities to rise from the current level of ~5/year to 10/year, and that the service activities will contribute to the participants’ sense of community, skill in teaching, and career development. GenOM also anticipates that 100% of the graduate students involved will graduate with their PhDs. All of the participants will be tracked for at least 10 years. The graduate students and postdoctoral fellows have access to $500 travel scholarships to attend science conferences for both presenting their research work and investigating postdoctoral and faculty career opportunities. Also, a stipend will be offered to those graduate students/postdoctoral fellows who serve as regular tutors, or who teach a defined class. The amount of the stipends vary depending on the time commitment and responsibility level.

Academic and personal advising is available for all graduate students and postdoctoral fellows participating in the UW GenOM Project. Career planning and postdoctoral/faculty opportunities are frequent topics, as are issues of research funding, national conferences, publication, and the PhD process, with a specific goal of helping graduate students with the grant writing process.

In conclusion, this paper has illustrated the programmatic elements of one program that has been successful at retaining underrepresented minority students in the STEM fields. GenOM has focused on intensive follow-up and monitoring of the students reaching across various levels in their college and graduate career. Whenever possible, GenOM has given their students opportunities to build communities in their groups and find memberships in the scientific community. These students also have had rigorous and equitable curriculum with research experiences that has provided them with the preparation to succeed in their science and engineering fields. GenOM will continue to serve the ethnic minority population and revise the program as the needs of these diverse students change over the years and strives to be a program that brings more ethnic minority students into the fields of science and engineering.
34. Shelton, B.L., Consent and consultation in genetic research on American Indians and Alaskan Natives. 2003.
42. Kurland, D.J. What is critical reading? How the language really works: The fundamentals of critical reading and effective writing 2000 [cited 2010 September 2].
65. Seelman, G., A scientist’s guide to making successful presentations to high school students: How to leave them asking questions and wanting more. 2003, National Institutes of Health: Bethesda, MD.


78. National Science Board, Undergraduate science, mathematics and engineering education: Role for the National Science Foundation and recommendations for action by other sectors to strengthen collegiate education and pursue excellence in the next generation of U.S. leadership in science and technology, H. Neal, Editor. 1986: Washington, DC.


