In-Depth Science Research Experiences for Teens:

The AMNH-ITEST High School Science Research Program

SUMMATIVE EVALUATION REPORT

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Executive Summary

In January 2005, the American Museum of Natural History (AMNH) was awarded a three-year ITEST grant (Innovative Technology Experiences for Students and Teachers) through the National Science Foundation (award #04-23417). This "AMNH-ITEST High School Science Research Program" aimed to target 120 urban high school youth, grades 10-12, from the five boroughs of New York City. Building on the previous similar program models, this ITEST program was designed to provide two years of immersion in technology-based scientific research – in this case, in genetics and astrophysics. Three cohorts of 40-50 students each (half in genetics, half in astrophysics) study the foundations of their chosen topic and learn to use advanced technology in conducting their own authentic research. Inverness Research has been the external evaluator for the project.

The AMNH-ITEST program is comprised of several core design features, including the following:

- The program is two years in duration
- The program targets 10^{th} or 11^{th} graders, especially those who are underserved in science
- The program includes in-depth summer sessions
- The first year of the program includes after-school or Saturday classes where students study genetics or astrophysics in depth
- The students are partnered with scientist-mentors who oversee their work in year two
- The second year of the program is an in-depth research experience where students work with scientist mentors doing authentic science research
- The program also assists students with college planning and career development
- The program is academically challenging and rigorous
- The program develops students' communication skills through student work on research papers and presentations
- The program is technologically rich

The driving theory behind this AMNH-ITEST program, (as has been the theory behind its predecessor programs ASCEND and PSC), is that if motivated students, no matter what their backgrounds, are provided with structured, challenging, science-rich, technology-rich, first-hand experiences, and supported with the wealth of the museum's resources, the result can be significant growth for students. In particular, it can result in growth of their content knowledge, technology and communication skills, study skills and work habits, attitudes, maturation, self-confidence, and expansion of their college and career ambitions.

Through our evaluation, we found the AMNH-ITEST program to have successfully met its goals of helping students gain experience with technology, developing specific scientific research skills, learning science concepts and increasing their awareness and commitment to STEM career paths. We found that the program proved to be not only enriching in those regards, but personally transformative for some students. In addition, we detected ways in which the AMNH-ITEST program benefited program-providers, i.e., program staff, mentors, and the museum in general. Highlights of our findings include:

- Students gained new knowledge and demonstrated understanding in science content areas
- Students gained new knowledge and demonstrated understanding about scientific research and the research process
- Students gained a better understanding of the role of technology in science
- Students expanded their awareness of potential STEM careers and the academic paths that can lead to those careers
- ITEST had a positive influence on participants' school work; in addition, students used their knowledge and experience gained from the program to benefit other academic endeavors outside of school
- Student became acculturated into a rigorous science environment
- Students expanded their sense of their potential
- Students learned how to be more responsible, and their study and work habits improved
- Students gained experience with and demonstrated improved skills utilizing a wide range of technologies
- Students demonstrated an increased ability to think logically and analytically
- Students learned about and demonstrated scientific research skills
- Students gained experience and improved their communication skills
- Mentors gained from having positive relationships with youth, which fueled their own enthusiasm and inspired their work; for some, students' contributions to mentors' research projects were notable
- Program staff increased their skill in working with youth and scientist-mentors; the program helped increase inter-departmental

communications within the museum, and the program helps the museum meet its mission of serving the local community.

Areas of challenge and opportunity for the program include recruitment of students to ensure that the program maintains a high level of diversity among student participants; the need for continued and ample documentation of the program, including its students, mentors, and alumni. In addition, significantly, recruiting, training and supporting the mentors in their work with the youth will take ongoing, concerted effort to ensure the best experiences for all involved. Program staff need ongoing support within the larger education department and institution, and opportunities to reflect on the program.

The following report includes more in-depth information about the AMNH-ITEST program, nature of the youth experience, benefits of the program for youth, mentors and the museum, and program challenges and opportunities, as well as an appendix with stories of four case study students.

Introduction and Background

American Museum of Natural History

The American Museum of Natural History (AMNH)[1] in New York City is one of the world's preeminent institutions dedicated to scientific research, exhibition, and education. Established in 1869, this multifaceted institution has long been a leader in exploring the natural world and human cultures, advancing the theoretical sciences, and in conducting interdisciplinary research. A strong commitment to the integration of science and education is reflected in their mission: "To discover, interpret, and disseminate – through scientific research and education – knowledge about human cultures, the natural world, and the universe."

Located on the 18-acre Theodore Roosevelt Park in Manhattan's Upper West Side across from Central Park, the AMNH labyrinth-like "campus" is comprised of 27 interconnected buildings with 1.6 million square feet of state-of-the-art research laboratories, collection facilities, offices, a planetarium, IMAX theater, exhibition halls, and much more. In addition to temporary exhibition space, there are 45 permanent exhibition halls on everything from meteorites and minerals to mammals; from ocean life and mollusks to ornithology; from peoples of the world to evolution and biodiversity. There is the Rose Center for Earth and Space, the Hayden Planetarium, the Center for Biodiversity and Conservation, and the Sackler Institute for Comparative Genomics, as well as many other centers, departments and ongoing programs. Open to the public 363 days of the year, AMNH hosts approximately three million visitors annually.

The museum also happens to be home to one of the world's greatest natural history collections (over 32 million specimens and artifacts)[2] and a library[3]. More than 200 scientific personnel, including some 40 tenure-track curators, manage the collections, conduct laboratory research and training, and carry out over 120 field expeditions and projects each year.

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[1] For more information about AMNH, see their website, www.amnh.org.
[2] Only a small fraction of the museum's collections are actually on exhibit at any one time.
[3] The museum's library, which is not open to the public, contains more than 450,000 volumes of books, monographs, magazines, pamphlets, original illustrations, archives and manuscripts, as well as multi-media, fine art, memorabilia and a rare book collection.

Both at the museum and out in the community, the Education Department offers programs and classes for all ages through the Gottesman Center for Science Teaching and Learning, the National Center for Science Literacy, Education and Technology, a Moveable Museum (in a converted Winnebego), and diverse other programs. Each year, approximately 460,000 schoolchildren visit AMNH and nearly 7,000 teachers receive professional development training. Covering the spectrum of life-long learning from pre-school on up, the museum also has programs for undergraduates, conducts a doctoral and post-doctoral training program, and recently launched a new PhD program in Comparative Biology.

All this is to say that the American Museum of Natural History has a phenomenal wealth of resources to support such programs as ITEST.

ITEST Initiative

The National Science Foundation initiated the Innovative Technology Experiences for Students and Teachers (ITEST)[4] program in 2003 to help address concerns about shortages of information technology workers and STEM[5]-focused students and teachers in the United States. The ITEST program has funded five cohorts of approximately 100 projects across the country. By exposing participants to project-based, experiential STEM learning, it is hoped that these programs will help school-age children and teachers to build skills and knowledge needed to advance their study and to function and contribute in a technologically rich society. One goal of the ITEST initiative is to increase the diversity of students entering STEM careers, therefore exploring career options is often an integral part of the programs.[6]

> As the 20th century fades into history, it takes with it the old industrial economy in which plentiful manufacturing jobs offered millions of people without a college education a ticket to the middle class. The 21st century's information economy is creating more jobs that require not only a college education but also at least some expertise in the fields of science, technology, engineering and math, collectively known as STEM. In order to stay competitive in the global marketplace and provide our children with the best chance to succeed in life, we must get more students on the STEM path. All across the country, schools and communities are using the hours after school to do just that. *(Continued on next page)*

[4] Formerly called Information Technology Experiences for Students and Teachers (ITEST).
[5] Science, Technology, Engineering, and Mathematics (STEM).
[6] For more information about the ITEST initiative, please see the ITEST Learning Resource Center's website: http://www2.edc.org/itestlrc/default.asp.

The U.S. Department of Labor is projecting that jobs requiring training in STEM will increase by 51 percent between 1998 and 2008, four times faster than overall job growth. By 2008, some six million job openings for scientists, engineers, and technicians will exist. Unfortunately, American students are losing ground to their international peers when it comes to earning degrees and going into careers in those lucrative, burgeoning fields.

- In 2005, roughly 29 percent of fourth- and eighth-grade students participating in the National Assessment of Educational Progress (NAEP) reached or exceeded the proficient level in science. Among 12th-graders, only 18 percent reached or exceeded proficient. In 2007, 39 percent of fourth-grade participants and 32 percent of eighth-grade participants scored at or above proficient in math.
- In 2006, 15-year-olds in the U.S. ranked 22nd in math and 19th in science among developed nations. Among these countries, the U.S. has the fourth largest gap between high- and low-income students.
- Among high school graduates, the percentages of blacks and Hispanics ages 25 to 29 in 2000 who had completed bachelor's or higher degrees in science and engineering stood at 21 percent and 15 percent respectively, compared with 36 percent for whites.

Excerpt from **"Afterschool Programs: At the STEM of Learning"**
Coalition for Science After-School, Issue Brief No. 26, January 2008

History of AMNH After-School Youth Programs

First, in order to better understand the AMNH-ITEST program, it is helpful to have a sense of the context within which it sits as part of the overall AMNH after school youth programs. As with most educational infrastructures, the AMNH youth programs have evolved and changed over the years, yet their mission for serving youth – especially underserved youth – has remained strong.

In response to the national crisis in STEM education, and partly in response to local educational needs, AMNH created a "pipeline" whereby students can start in after school programs as early as pre-school and participate in various activities all the way through high school and beyond. Currently, the museum hosts more than 700 students per year in their after school programs.

Capitalizing on the museum's unique assets to enrich such programs, AMNH began developing more in-depth, long-term experiences for high school students, precursors to ITEST. One of the first such programs began in 1992, the Precollege Science Collaborative (PSC). In this program, small groups of underrepresented and minority youth spent two years, approximately 10 hours per week, learning about the museum and various scientific disciplines, carrying out research alongside a scientist mentor, participating in field trips and special events, and preparing for college. As a culminating event, students presented findings from their research to museum staff, scientists, and family members. The experience proved transformative for many participants.[7]

Based on the success of the PSC program, and in an effort to involve more youth in after school programs, in 2001, AMNH staff designed the High School Science Research Program (HSSRP). The HSSRP is a collection of programs funded by local, state and national funders. The program involves four areas of science research: genetics, astrophysics, biodiversity and anthropology. Hundreds of youth participate in HSSRP summer institutes, then choose from a series of after-school courses the following year.[8]

The next evolution of in-depth youth programs at AMNH was the After School Center for Explorations and New Discoveries (ASCEND) program. Beginning in 2002, ASCEND offered after-school experiences to high school students similar to the PSC program, but specifically in the fields of genetics, genomics and genethics.[9] In the first year, youth participated in courses, lab work, and group projects two days a week. Topics included a history of genetics and related fields, laboratory procedures and safety, DNA cloning and amplification, DNA sequencing and microarray, and bioinformatics. During the second year, youth participated in independent research with scientist-mentors at the museum or collaborating institutions such as Rockefeller University, the Wildlife Conservation Society, and the Sloan Kettering Institute. Also in the second year, students met monthly as a group with program leaders to discuss current topics in genetics, share progress on their research, investigate possible careers, and prepare for their final research presentations. Students also received extensive SAT test preparation and went on occasional field trips. This, like PSC, proved to be a highly successful program.[10]

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[7] The PSC program ran from 1992-2002 and served 74 students in nine cohorts. Inverness Research studied the program in 1998, assessing the program through program observations; interviews with and surveys of youth; and interviews with staff, scientist-mentors and parents. In addition, Inverness did longer-term studies of the PSC graduates, talking with them shortly after they graduated and five years later.

[8] For more on HSSRP, see http://www.amnh.org/education/students/program.php?id=204 .

[9] A total of 52 students in three separate cohorts were served through the ASCEND program from 2002-2006. Students were selected after participating in an HSSRP summer institute and were chosen based on their interest in genetics and available openings in the program. The majority of participants were female youth of color.

[10] Inverness Research conducted a summative evaluation of the ASCEND program in 2004-2005. We observed classes, special events and the graduation ceremony of the second cohort; interviewed and conducted focus groups with participating students; interviewed scientist mentors; and conducted formal and informal interviews with parents and family members.

Continuing to build on their successes, AMNH Education Department staff took the opportunity through the ITEST initiative to further develop and institutionalize their in-depth science research program for youth.

AMNH-ITEST High School Science Research Program

In January 2005, AMNH was awarded a three-year ITEST grant through the National Science Foundation (award #04-23417). This "AMNH-ITEST High School Science Research Program" aimed to target 120 urban high school youth, grades 10-12, from the five boroughs of New York City. Building on the PSC and ASCEND models, this ITEST program was designed to provide two years of immersion in technology-based scientific research – in this case, in genetics and astrophysics. Three cohorts of 40-50 students each (half in genetics, half in astrophysics) study the foundations of their chosen topic and learn to use advanced technology in conducting their own authentic research. (Actual numbers served by this ITEST grant were 39 in Cohort 1, 45 in Cohort 2, and 35 in Cohort 3, for a total of 119.)

During their first year, participants attend a one to two week summer session, and then attend a series of classes at the museum four-to-six hours per week throughout the school year. During their second year, students work closely with a scientist mentor on a particular research project. They must prepare and present a scientific research report. Woven throughout the program are behind-the-scenes tours of the museum, field trips, special guest speakers, college fairs and SAT preparation support.

The driving theory behind this AMNH-ITEST program, (as has been the theory behind its predecessor programs ASCEND and PSC), is that if motivated students, no matter what their backgrounds, are provided with structured, challenging, science-rich, technology-rich, first-hand experiences, and supported with the wealth of the museum's resources, the result can be significant growth for students. In particular, it can result in growth of their content knowledge, technology and communication skills, study skills and work habits, attitudes, maturation, self-confidence, and expansion of their college and career ambitions. In other words, the experience can be not only enriching, but transformative. (A more detailed explanation of the program and its theory of action follows in the next section "Program Description".)

Inverness Research and the AMNH-ITEST Evaluation

Inverness Research, Inc. is a private education consulting and evaluation firm based in Inverness, California.[11] As footnoted above, we have been external evaluators for other AMNH student programs (PSC and ASCEND) as well as a teacher professional development program (AMNH's Seminars on Science). Our previous work with museum (both formative and summative evaluations), coupled with our extensive experience evaluating a wide range of formal and informal education programs around the country and our national perspective on science education, has afforded us a useful vantage point from which to conduct this AMNH-ITEST evaluation.

The approach we used for the AMNH-ITEST evaluation entailed:

- Documenting the program in terms of design, implementation and impacts – researcher as documenter
- Groundtruthing – researcher as detective, exploring how well on-the-ground realities match the program's theory of action and goals
- Providing an outside perspective on the quality of the program
- Taking a long-term view of AMNH's evolving programs, trying to glean lessons learned for them and the field
- Giving formative feedback to staff about the program – serving as critical friend by feeding back data, observations, and insights along the way and serving as a sounding board for staff deliberations
- Using multiple methods, data sources, and investigators (researchers) for triangulation of findings

Specific methods used for this ITEST evaluation included:

- Program **observations** – attended classes, meetings, field trips, special events and graduation ceremonies
- Ongoing formative work – **discussions** with staff in-person, by phone and email
- Baseline and end-of-program student participant **surveys**[12]

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[11]For more information on Inverness Research, Inc., including evaluation reports on various educational programs, see our website at www.inverness-research.org.

[12] The first and second cohorts completed 6-page "Baseline" or pre-program surveys, and 7-page "End-of-Program" surveys. Ninety-five percent of 126 ITEST participants responded to the surveys. This represented 93% of the students attending the Genetics program and 100% of students attending the Astrophysics program.

- Parent surveys
- **Individual interviews** with students, parents, scientist mentors, and program staff
- In-depth interviews and email surveys with eight **case study** students throughout their two year program
- **Focus groups** with students, parents and mentors
- **Scan of the field** – research into what other similar programs exist around the country
- **Document review** – examined program documents and student work (student work included journals, class worksheets and quizzes, lab data sheets, and final research project papers, posters and power point presentations)

Drawing upon our longitudinal perspective of the AMNH youth programs, one of the reports we completed and disseminated as part of this ITEST grant is called "Ten Years of Youth Programs at the American Museum of Natural History: An Independent Perspective and Lessons Learned".[13]

Next, we will take a closer look at the AMNH-ITEST program – its theory of action, core design features, and the nature of the youth experience.

Program Description

> "The project builds and extends on a prior pilot project that involved high school students in educational programs in the areas of genetics and astrophysics. Through these program partnerships have been created and will be part of the project. Students will learn to use advanced information technology as used in current scientific research rather than working through a series of classroom examples. The goal is for students to gain experiences with IT tools, develop specific scientific research skills, learn science concepts and increase awareness of and commitment to STEM areas in college and/or professional life."
>
> *(Program overview from the AMNH-ITEST proposal)*

[13] An abstract and link to the full report can be found at http://www.inverness-research.org/abtracts/ab_20080114_amnhitest10yrs.html .

Theory of Action

Like its predecessor programs ASCEND and PSC, the AMNH-ITEST program is based on a certain logic model or "theory of action". Underlying that theory of action is a major premise that the American Museum of Natural History has a unique set of resources that can be brought to bear in providing high-quality, scientifically- and educationally-rich programming for students. These resources include the museum itself with its collections, exhibits, educational programs, research laboratories, and abundant, cutting-edge technologies. Resources also include the knowledge and expertise of scientists and science educators, as well as a shared institutional culture of rigorous scientific inquiry. AMNH reasoned that it could draw on these resources to create a uniquely immersive experience for high school students, particularly those students who otherwise might not have this type of opportunity.

Following this theory of action or logic model, the museum believed that they could attract several cohorts of motivated students, support them through a highly structured and challenging two-year program, and that through access to the museum's resources, students could have not only an enriching experience, but one that is transformative. In other words, students could acquire skills in technology use, scientific research skills, increased science content knowledge, and an improved ability to communicate scientific ideas. In addition, through the well-designed social and one-on-one aspects of the program, students could grow significantly in personal ways such as increased self-esteem, maturity, responsibility, self-confidence, and their ability to relate to and work together with others. Students' sense of college and career possibilities could also be expanded. In order to accomplish this, program leaders chose depth over breadth. That is, the program works with small numbers of students (40 per cohort) intensively for two years.

Lastly, part of the museum's theory of action for these youth programs is that through self-reflection and evaluation, they can learn from their successes and failures and share what they learn with a wider audience. Building on lessons-learned from previous similar programs, the museum can identify core design features that help make a successful program. Ultimately, AMNH hoped to create a program model that could be replicable at other informal science institutions.[14]

Core Design Features

Reflecting its theory of action, the AMNH-ITEST program has certain core design features which include the following:

- It is a two year program focused on a particular scientific discipline – in this case genetics or astrophysics.

- The target audience is 10th or 11th graders, especially those who are underserved in science.

- After an initial introduction to several scientific disciplines (e.g. genetics, astrophysics, anthropology and biodiversity) during a two week HSSRP summer session at the museum, students who are interested and highly motivated can choose to continue on with a year of classes focused on either genetics or astrophysics.

- During the first school year, students come to the museum after school (generally 4:30-6:30 p.m.) for two hours, twice a week, and participate in classes taught by program staff. In some cases, students attend a 6-8 hour every other Saturday session instead. Classes include review of scientific concepts, discussion about readings and science in the news, practice with lab techniques and becoming familiar with technologies involved in research and data analysis. There are occasional guest speakers. In addition, there are special events, lectures, and field trips.

- After their first year of classes, students must go through an application process in order to continue on to the second year research component.

[14] In our brief scan of the field, we found very few programs around the country of similar intensity and endurance. Most comparable programs involving high school students doing scientific research with a mentor typically take place over several weeks or at most one summer. We found nine programs where students are involved for approximately one year and conduct research. Five of those were offered through science museums, and four by universities or research institutes. Seven of those nine programs offer an approach similar to ITEST where students are involved in common learning experiences such as coursework and fieldtrips before they go on to a research internship appointment where they work with a scientist mentor.

- During the second summer, there is a two-week intensive session (full days, five days a week). This includes a mix of content review, practicing research lab techniques, preparing for the research project and mentorship experience, field trips, lectures and special social activities.

- Scientist mentors are recruited by AMNH-ITEST program staff through word-of-mouth, museum bulletins, and through curators and research lab directors. Depending on the interests and proclivities of the students and the availability and schedule of the scientist, program staff try to find an appropriate mentor/student match.

- During the second school year, students arrange a schedule with their scientist mentor that usually entails coming to the museum twice a week for a total of 4-6 hours to conduct research.[15]

- In addition to the second year mentorship, every other week students attend a two hour seminar with program staff to share their research experiences; review lab techniques, research methods, science content, and vocabulary; share mistakes, lessons-learned, and other journal reflections; discuss scientific journal articles they read; learn how to write a science research paper; and prepare for their final presentations.

- The students' time commitment to the program is significant. In addition to the 4-6 hours per week actually at the museum, many students have long commutes to and from school, the museum, and home. One to one-and-a-half hour commutes home after a long day are not uncommon.

- Within the two year program, students participate in career development discussions and special events (e.g. career fairs), and students are offered free SAT exam preparation support (the museum has a special arrangement with Kaplan[16] to help students prepare for SAT exams).

- Staff to student ratios are low. During classes and group events, there is often at least a 1:8 staff to student ratio. Students' research lab experience

[15] Survey respondents spent an average of six hours per week working on their research projects. The reported range was from 4 to 13.
[16] Kaplan is a national education firm that provides, among other services, test preparation courses and materials.

is either one-on-one with a scientist mentor, or in some cases, there are two students per mentor.

- The program leaders are either scientists with teaching experience or teachers with strong science backgrounds. The ITEST program sits within the museum's Education Department, thus can draw upon the significant resources and expertise of the other education staff, as well as that of other museum departments.

- The program is academically rigorous and challenging. The genetics and astrophysics content level is high. For example, genetics students learn about DNA sequencing, polymerase chain reactions, and gel electrophoresis. Astrophysics students study quasars, advanced physics and chemistry, and black body radiation – topics normally reserved for astrophysics majors in final years of college. As one staff member put it, "*These students are getting experience with research scientists that usually is reserved for grad students.*"

- Developing scientific habits of mind and expanding students' vocabulary is emphasized. Students are encouraged to keep a journal or lab notebook. Reading and discussing scientific papers and journal articles are common throughout the two year program. Students occasionally attend scientific lectures. One mentor said, after giving the students an article to read, "*Even my colleagues don't read this, it's too hard. But that doesn't stop these kids*!"

- Some students come to the program with more academic background and propensity than others. Efforts are made to support and bring up the level of those with less background so that there is a more level academic playing field across the cohort.

- Students' communication skills are developed throughout the program. For example, students are encouraged to take an active role in class discussions, actively debate ethical issues, and to present summaries of science articles they read. At the end of their second year, in addition to preparing a paper about their research findings, students prepare posters and power point presentations for the graduation ceremony.

- Field trips and social events are woven into the two year experience. Field trips have included visits to Stony Brook University, Columbia University, Sloan-Kettering Institute, Pfizer, and Rockefeller Institute for Medical Research. Social outings have included camping trips, bowling parties, picnics, and movie nights. Describing the events of a summer session, one student commented:

> *Summer was amazing! We had two weeks of classes. We went over the radio telescopes and how galaxies were formed, different types of galaxies, and how they're destroyed. We did activities about Edwin Hubble, and his classification system . . . learned a lot about astral things. We went to see the film "An Inconvenient Truth," it opened my eyes a lot. I didn't know how energy-guzzling we are. I didn't know about our energy consumption and how we stack up against other countries. We also went to Rye Playland, an amusement park. And also we had a star wars-themed party, that was fun.*[17] *(Student)*

- Students are exposed to and use a wide variety of technology equipment and systems throughout the two year experience (more on technology use below).

- There is a strong emphasis on encouraging and welcoming diversity – i.e., ethnic, socio-economic, gender, age and academic diversity. Among program staff and scientist mentors, there happens to be a high percentage of women and non-Caucasians, providing students a positive alternative role model compared with the "white male scientist" stereotype still prevalent in society. Museum staff and mentors that the students interact with regularly range in age from early 20s to seniors, and some are English-Second-Language speakers. The majority of students are non-Caucasian (15% Hispanic/Latino, 17% African-American, 34% Asian, 26% Caucasian, and 8% Other/Don't Know), many are from lower socio-economic households, and they attend a wide range of mostly public high schools throughout the city. There are slightly more female students than male.

- The programs seeks the involvement and support of parents and family members. There are special meetings and events for parents to learn more about the program and resources available to them; for example, regarding the college application process and financial aid. Parents and family are the special guests of honor at the program's graduation ceremony where students present their final research projects.

[17] Some quotes have been lightly edited for clarity or to ensure anonymity.

- The program is free, and students receive other types of support in addition to SAT exam preparation. They receive public transportation vouchers to help cover commuting expenses. Snacks are provided during late afternoon classes, and meals are provided when programs occur during breakfast, lunch, or dinner hours. Field trip expenses are paid. And, as part of the program, students who finish the two-year program receive a stipend.

- Exposure and access to many of the museum's resources is an integral part of the program. Students receive a photo-ID badge that gives them staff-like access to the museum, exhibit halls, offices, and to the in-house research library (described in the introduction section). Accompanied by staff, students have access behind-the-scenes to the museum's research laboratories, storage rooms, and numerous collection facilities (e.g. the Ichthyology Department's three floors of fish specimens from the late 1800s to present, and the Ambrose Monell Cryogenic Collection for Molecular and Microbial Research where students can view tissue samples of thousands of organisms in vats of liquid nitrogen). Many of the museum's exhibit halls are utilized for classes such as the Spitzer Hall of Human Origins, the Hall of Biodiversity, the Gottesman Hall of Planet Earth, the Hayden Planetarium, and numerous temporary exhibits.

- Building on the museum's interdisciplinary approach to the sciences, students are exposed to and gain experience with a variety of disciplines such as biology, conservation biology, zoology, physics, chemistry, geography, anthropology, paleontology, geology, mathematics, art, and humanities

- The lab-based research that students conduct during the second year of the program is highly authentic. Students work on projects alongside their mentors, and these projects are not fabricated scenarios meant solely for student practice; rather they are part of the very real research of that particular mentor. On occasion, after students show a capacity for independent lab work, mentors supervise the students in conducting their own separate-but-related research. In some cases, research that students conduct becomes a part of their mentor's published research findings. Students' final research papers and presentations reflect the authenticity of their research experiences.

Examples of Student Research Projects

- Understanding the History of the Universe by Analyzing Basic Characteristics of Quasars
- The Molecular Relationships Within the Southern African Frog Genus *Cacosternum*
- Genetic Diversity in Polar Bears from Nunavut (Canada)
- Measuring Morphological Diversity in Cichlids from African Rivers and Lakes
- In Search of the Squirrel Monkey Retrovirus in South American Rodent and Bat Species
- Using Phylogenetic Techniques to Compare Proteins Found In Mammalian Eosinophils
- The Use of a Mitochondrial Gene Sequence to Demonstrate Relationships Between and Within Species of Caimans
- Monitoring the Behavioral Effects of Satellite-tracking Devices on Flamingos
- Distribution of Common Tern Nests on Great Gull Island
- The Phylogeny of Bat Flies
- Comparison of Endocasts of Extant and Fossilized Penguins
- Calculation of the Rotational Curve of the Milky Way Galaxy (using the museum's 21-cm radio telescope)
- The Identification of Black Holes Using Data from the Chandra X-Ray Observatory

Technology Use

As mentioned above, the integration of technology into AMNH-ITEST activities is one of the program's core features. Students have access to an abundance of high-tech, state-of-the-art equipment, especially during their second year conducting lab research alongside their scientist mentor. Here is a sampling of technological equipment and systems that students utilize in the AMNH-ITEST program:

- Electron and binocular microscope

- Variable volume pipettes
- Gel electrophoresis
- PCR machines (extracting DNA, running sequences)
- Microcentrifuge
- Autoclave
- Digital calipers for measuring
- Astronomical data sets from sources such as the Sloan Digital Sky Survey and the Chandra X-ray Observatory
- Optical and radio telescopes
- Digital cameras and sophisticated photo editing programs
- GPS and GIS systems
- Scientific calculators
- Computers for word-processing; creation and use of data bases, spreadsheets, graphs and charts; desk-top publishing and graphics applications; multi-media; and creation of Power Point presentations.
- Sophisticated and specialized computer programs (e.g. genetic tree building and character mapping, Interactive Data Language (IDL) for astronomical data analysis)
- Digital cameras and projectors
- Classroom "Smart Board" (interactive white boards for giving power point presentations, showing something online, drawing, etc.)

One student commented on the technology use in the program:

> *The PCR machines are great. We have these huge banks of machines so if you want to do something like optimize a PCR, you don't have to wait in line and run it in the same machine, there are 10 machines available and you can put a different sample in each one. The sequencer I think is a ABI3730…it is nice to have in-house sequencing . . . A lot of start-up labs will send out to get their sequencing done. We have a PCR cleanup robot too, it does the PCR cleanups and the cycle sequence cleanups for you. All this is really handy. (Student)*

As a non-profit institution, the museum's wealth of high quality, cutting-edge technology comes through the generosity of many donors. Museum staff are keenly aware of their good fortune in this regard, and in cases that we observed, they tend to pass on a sense of respect and care for the equipment to the students. The program also benefits technologically in that there is often staff dedicated to the care and maintenance of the equipment and systems.

Nature of the Youth Experience

So far in this Program Description section we have discussed the theory of action, core design features, and technology use of this AMNH-ITEST program. Here we want to give the reader a sense of the program in terms of its atmosphere, mood, and culture. In order to do that, we include highlights of two program components – the summer *Tree of Life* workshop with teachers, and the second-year research experience. Overall, as we have observed and as our data suggest, the AMNH-ITEST program provides a high-quality, warm, welcoming, and exciting venue for high school students to learn and grow.

> The great majority of parents surveyed rated the ITEST experience for their child as "high quality."

Tree of Life Workshop

During the second summer, students come together for two weeks. The first week they participate alongside a group of teachers in a "Tree of Life" workshop. As part of the outreach for an NSF CIPRES grant[18], AMNH offers this workshop for students and teachers focused on phylogenetic research, looking at the mechanisms of evolution at the genomic level. The workshop draws on the work of AMNH's own Ward Wheeler, Curator with the Division of Invertebrate Zoology, who developed a complex computational method of systematics for assembling the Tree of Life or map of organismal evolution.

During the first summer (2006) that this workshop took place with ITEST students, there were 12 students and 16 teachers. The second year (2007) there were 16 students and 12 teachers. There was an emphasis on technology, e.g., computers with sophisticated scientific software and familiarizing participants with GenBank (A database of nucleotide sequences maintained by the U.S. National Center for Biology Information). The Tree of Life mapping method was subsequently utilized by the ITEST students in analyzing their research data and for use in their graduation presentations.

[18] The CIPRES project is a multi-site collaboration funded by the NSF Information Technology Research (ITR) program grant entitled "BUILDING THE TREE OF LIFE: A National Resource for Phyloinformatics and Computational Phylogenetics."

Reflecting on the Tree of Life workshop, staff observed that "the students knew more than the teachers . . . they had a leg up!" This was likely due to the genetics courses taken during their first year of the ITEST program. Staff reported that students enjoyed being in that unique position of "knowing," in reversing roles and being able to help others, and that they relished giving teachers feedback on their work. Program staff also felt that the peer-to-peer interactions with teachers helped humanize teachers for the students, and likewise, it "helped the teachers to see that high schoolers could reach this level."

After the Tree of Life week with teachers, ITEST students spent the second week of their summer session with program staff focusing on college preparation and career development. They took field trips, e.g., to Wyeth Pharmaceuticals in New Jersey and Rockefeller University. They got to see and talk with college interns, medical students and Ph.D. students – ate pizza with them and shared experiences about applying to college, career choices, etc. After spending every day together for two weeks, staff reported that students formed a strong group identity and that this carried over into their second year of the program.

The Second Year Research Experience

Based on our observations and experience with other educational programs in diverse settings, we believe that museums, and in this case AMNH in particular, provide a unique setting and infrastructure for youth programs. AMNH's after school programs, including ITEST, endeavor to create an exciting and vibrant learning environment. This is not difficult to do because, unlike a university for example, the ITEST program has the whole museum with all its resources and full range of staff to draw upon, not to mention the energy and excitement of the throngs of visitors that students pass on their way to class and to their research labs. Also, by engaging many levels of museum staff – from research scientists, curators, and exhibit developers to educators, technology specialists, and administrators – the ITEST program creates a distinctively rich program that models inquiry and a collaborative approach to learning. The program is inclusive and strives to welcome all students with respect and appreciation. It cares about learning, but it also cares about the individual learner and actively embraces diversity. AMNH is lauded for creating this comfortable and nurturing yet invigorating sense of home for students.

When we look closely at the nature of the youth experience in the ITEST program, especially during the second year research mentorship and during their bi-weekly group sessions, we see a high-quality experience that is frequently characterized by good-hearted humor and fun mixed with professional seriousness and intellectual rigor. Utilizing a heuristic teaching method, program staff and scientist mentors treat students as colleagues and with respect. Students are challenged, yet they are encouraged and supported. Many of the museum spaces that students spend their time in are clean, organized, well-lit, modern, and aesthetically sharp rooms with state-of-the-art equipment (e.g., the new Sackler Educational Laboratory), all of which sets them apart from the commonly bare and dingy classrooms that students experience in their schools.

In the research labs, students work closely with their mentors conducting research. For example, a mentor might walk the student through a certain task and stand by while the student tries the technique. Once the mentor is confident that the student has the skills and understanding to complete the task independently, the mentor moves on to do something else in the lab or back at his or her desk. This trust not only empowers the student but instills a sense of responsibility and confidence. The mentor is nearby and available should the student have questions or encounter problems. Thus, this independent and at the same time highly supported approach tends to create a positive and motivating atmosphere for the students, who in turn, take their work seriously and do a good job.

> *Kids usually come in with the Discovery-channel views of science and don't realize the hours of mosquito-bitten observation required or the monotonous, repetitive tasks and hours that are involved in research. These [ITEST] kids come away with a more realistic view of science research. (Staff)*

> *This lab/research experience helped give him [the student] direct exposure to technique and rigor. (Parent)*

<u>Lab Research Examples: Windows into the Nature of the Youth Experience</u>

- Identifying species of marsupial through DNA analysis using gel electrophoresis.
  The gel electrophoresis we did on the marsupial tissue worked! You can see the bars showing the DNA sequence. Our mentor was excited because she'll be able to use that when she goes to Brazil to work on this. (Student)

- Examining catfish from Peru, trying to determine if they are the same species as previously identified or a new species. There is a sense of

urgency. The students love it when they notice something that the scientist missed, or when the scientist makes a mistake that they catch. Skills they are using include observation, measuring, looking for patterns, working with hypotheses, and using dichotomous key.
We like what we're doing. We're looking at hypoptopoma, catfish, trying to figure out what species they are. We found a problem with the scientist's ID key. . . it's got morphological features. . . the 'Caudal-peduncle' point. That was cool! (Student)

- Using morphometrics, comparing species of fish, revising phylogenetic order to see if they are a new species. Regarding learning the importance of backing up computer work:
  We lost all the data! We had to start all over again. I don't know how it happened, it just disappeared! It's stored in computers in the dungeon [basement], in the computer room. Now we email the data to each other and save it on USB. (Student)

- Working with tissue samples from a type of nearly extinct dolphin from Vietnam – taking samples, extracting DNA, and trying to determine if it is an independent species.
  I made a big mistake. I used ethanol before putting it in the incubator . . . I was so scared . . . I thought she [the mentor] would be really mad, but she didn't yell or get mad or anything. I redid it, and ran the PCRs. It's pretty fun. You have to be careful though. (Student)

At the end of the second year, students present their research findings at a "graduation" ceremony held at the museum. This special event draws parents, brothers and sisters, and other family members or caregivers, as well as school teachers, friends, and the AMNH program staff and mentors. There is a festive atmosphere with food and mingling. There are brief staff presentations about the program, but the main focus is on the students and their research. The atmosphere and mood, like other aspects of the program, is very student-centered.

> *We [the student's family] are of modest means, and we are truly grateful that this program is free and accessible to all students in NYC. (Parent)*

> *I am glad for all the wonderful times and that we have been through everything together as a community for the past two years. (Student)*

The nature of the AMNH-ITEST participant experience, as we observed and have tried to convey in this section, was overall very positive, healthy, and strongly supportive of personal and academic growth. The experience results in a sense for students that the AMNH is actually a "home away from home" – it is an intellectual, friendly, and supportive community of scientists and educators devoted to making a substantive long-lasting and positive impact on local high school students from under-served populations.

In the next section we explore specific benefits and impacts of the program for the students, scientist mentors, program staff, and the museum as a whole.

Benefits and Impacts

We found the AMNH-ITEST program to have successfully met its goals of helping students gain experience with technology, developing specific scientific research skills, learning science concepts and increasing their awareness and commitment to STEM career paths. We found that the program proved to be not only enriching in those regards, but personally transformative for some students (see Case Studies in Appendix). In addition, we detected ways in which the AMNH-ITEST program benefited program-providers, i.e., program staff, scientist mentors, and the museum in general.

This appraisal of benefits and impacts is based on our three years of ITEST-specific observations, interviews, focus groups, surveys, case studies, informal conversations, reviews of program documents, reviews of student journals and final projects; and this appraisal draws upon our ten-year experience of studying other AMNH after school programs for high school teens. These findings also draw upon our perspective as evaluators having studied hundreds of formal and informal educational programs around the country for the past 25 years. We attempt to convey here not only the ways in which, but also the extent to which the AMNH-ITEST program benefited and impacted participants.

Student Benefits and Impacts

According to our data, the program proved to be very beneficial to students in numerous ways. It can be helpful to think of these benefits in several distinctive yet overlapping categories:

- Awareness, Knowledge and Understanding
- Engagement and Interest

- Attitudes and Behavior
- Skills

Awareness, Knowledge and Understanding

- **Students gained new knowledge and demonstrated understanding in science content areas** – particularly in genetics and astrophysics, but also in biology, chemistry, physics, anthropology, zoology, etc.

Student survey results showed an increase in students' content knowledge. When surveyed at the beginning of the program (baseline survey), 29% of the students said that they knew "a great deal" about genetics, and that number went up to 57% by the end of the program (end-of-program survey). With astrophysics, 30% rated their knowledge as "a great deal" at the beginning of the program, 56% by the end of the program. Students attributed their increased content knowledge to the AMNH ITEST program. In end-of-program surveys, 63% of the students said that they had learned "quite a bit" or "a great deal" about genetics through the program, and 72% said the same about astrophysics.

I believe this program opened opportunities for me in biology and other fields. It gave me a chance to pursue things that I would never [have] been able to pursue in school. (Student)

My son experienced doing more research type projects at a level higher than he has known in high school. It has opened his horizons to different types of sciences and venues in which he may decide to work. (Parent)

I think my daughter gained a great deal from her mentor and the people she worked with in term of knowledge and being able to study a variety of subject matter. Of course, the resources she was able to access working at the museum have been invaluable. (Parent)

- **Students gained new knowledge and demonstrated understanding about scientific research and the scientific process.**

Student survey comments reflected their increased awareness of how time-consuming, challenging, and strenuous scientific research can be and the commitment required.

Eighty nine percent of survey respondents rated their research experience as valuable to extremely valuable.

Scientific research is much more in depth than I thought, and requires much knowledge and understanding to complete projects (research). (Student)

My definition of scientific research after this program is that it is a serious and intuitive search for the sake of curiosity. (Student)

To start off, my school has a science research program and they define it as an independent study of a particular area of interest. This "independent" research consists of reading research papers written by other scientists. With the science research program at AMNH, however, research is a collaboration between students and teacher scientists and results in the gathering of information – not from solely reading papers – but actually from doing research. (Student)

I realize now the level of in-depth research and commitment that goes into each and every scientific research paper. (Student)

- **Students gained a better understanding of the role of technology in science.**

In end-of-program survey comments, numerous students mentioned learning from the program about the critical role that technology plays in scientific research, and how actually doing research and using different kinds of technology in the program played an important role in shaping their new understanding.

Eighty seven percent said that they better understand the role of technology in science as a result of this program.

My knowledge has expanded about using technology with science. I learned how to edit DNA sequences on the computer by comparing the forward and reverse sequences, as well as making a variety of phylogenic trees. (Student)

With the level of research performed in this program, computer literacy is required, and I really learned how technology and science has been incorporated and supplement each other. (Student)

I am now more knowledgeable about what paleontologists really do and have had an inside glance at the work environment. I also got to use some relatively novel technology and see the impact it will have on my field in the future. I feel more prepared for paleontological research now. (Student)

- **Students' ideas of what science is – what scientists look like and what they do – grew and matured.**

Most of the students' survey comments indicated that their image of science and what scientists do expanded. Their ideas of scientists went from stereotypical images of men in white lab coats who focus solely on their research, to images of diverse, well-rounded people who also contribute to the community through their work. Some students noted how intense and time-consuming being a scientist can be.

I always thought of scientists in lab coats working on top research having little or no time to guide youth interested in the field. Now I know it is a wonderful community, and this has influenced my choice of college major. (Student)

I knew what the job of a paleontologist was, but had always heard more about field work than lab work. This program gave me insight into what goes on in the lab and how discoveries are made. (Student)

- **Students expanded their awareness of potential STEM careers and the academic paths that lead to those careers.** They were exposed to information about college programs and careers related to genetics and astrophysics, as well as other disciplines. The program helped most students discover or clarify what they are interested in pursuing, and for a few, the program helped them recognize what they are <u>not</u> interested in doing.

A majority of ITEST participants are planning to go on to college and stated that their participation in the AMNH program influenced their plans. Fifty seven percent reported that they planned to pursue a doctoral degree, while another 29% reported that they planned to pursue a master's degree. Fifty seven percent of survey respondents reported that the program had greatly influenced their thinking about college, while another 54% reported that their experiences in the program had greatly influenced their thinking about careers. Survey comments support this survey data. College and career plans include pursuing science, engineering, the medical field, and education. Several students mentioned wanting to go into astrophysics or genetics.

From the baseline to the end-of-program survey, most students indicated a fairly significant change in their college plans. Specific examples include:

- from being unsure about college to planning to pursue a master's degree
- from wanting to go to a two-year or technical training school to planning to pursue at least a master's degree
- from being unsure about college to planning to attend a four-year college
- from planning to pursue a two or four-year degree to going for a PhD
- Six students went from planning to attend a two-year college on their baseline survey to planning to pursue a master's or doctoral degree on their end-of-program survey.

Only two students indicated no change in their college plans from baseline to end-of-program survey.

I plan to major in Biology for my bachelor's degree. I plan to continue my education in graduate school for a doctoral degree. (Student)

I'm planning on taking advantage of MD PhD programs along with dual degrees. (Student)

I want to be an astrophysics researcher. (Student)

I will go into vertebrate paleontology, specifically, dinosaur paleontology. (Student)

It [the program] helped my daughter choose a major for college. (Parent)

The experience shakes up students' notions that the only kind of career path for science is medical school. The mentorship opens up more options and avenues for students. (Graduate student/research scientist mentor)

The comparison of student comments between the baseline and end-of-program surveys with regards to career objectives shows that for some of the participants, their career goals were clarified or sharpened.

I see myself in a career in biotechnology or with computers. (Student, pre-program) An astrophysics career or chemical engineer. (Post-program)

I want to attend college in order to pursue a career in Mechanical Engineering. (Student, pre-program) I see myself as a successful engineer. (Post-program)

I see myself being some kind of researcher for some space project. I am interested in a career in astrophysics working at either NASA or Columbia. (Student, pre-program) I see myself as an astrophysicist researcher. (Post-program)

I am interested in finding out more about computer engineering and being a DA. (Student, pre-program) I want to become a pediatric medical doctor. (Post-program)

I see myself doing something I love, either working in space on the International Space Station or creating the next part of it. (Student, pre-program) I am interested in being a doctor at Columbia University. (Post-program)

I see myself in either the field of genetics, engineering, medicine or a mixture of the three. (Student, pre-program) I see myself working in a biology-related job, perhaps biotech. (Post-program)

End-of-program survey data show that the Astrophysics and Genetics programs met or exceeded participants' expectations. Almost half of the astrophysics students rated the program as "far exceeding their expectations" (a five on a 1-5 scale, 1 = did not meet my expectations and 5 = far exceeded my expectations). The majority of genetics students rated this a 4 or 5.

Engagement and Interest

- **ITEST had a positive influence on participants' school work.**

Fifty nine percent of survey respondents agreed with the statement "I have been taking more math and science classes, partly due to this program." Forty-one percent agreed with the statement, "I have been taking more challenging math and science classes, partly due to this program." Moreover, ITEST participants have been able to apply what they learned in the program to their school science experiences. Fifty-two percent agreed with the statement "I have engaged in science projects at school that were influenced by my experience in this program." In addition, 44% agreed with the statement, "I have used research skills that I developed through this class for other classes at school."

> *She [the student] because more focused academically, especially in the school sciences of biology and physics. (Parent)*

- **Students used their knowledge and experience gained from the program to benefit other academic endeavors outside of school.**

Fifty-nine percent agreed with the statement, "I have used what I learned in this program for out-of-school events like science fairs."

> *The most important things I learned involved the modern, up-to-date research technologies used to study specimens. Also, I wrote my very first research paper that I will now use as a template for science competitions that I may enter. (Student)*

Attitudes and Behavior

- **Students gained social and personal skills such as increased self-confidence.**

> *I now know more than before, and that gives me a lot of confidence. (Student)*

> *This is an amazing program that helped me see what I want to do for the rest of my life and it helped me gain confidence in my abilities. (Student)*

> *There has certainly been a positive change. Our son became more focused, and he selected his goals for the future while working at AMNH. We have seen our son's social and academic progress during the last two years. It [the ITEST program] has made him self-dependent, more humble, and much more self-confident. (Parent)*

> *The museum has become an anchor in her life. She's stuck with it. She's not always the most focused student, but she kept coming. There's a lot of social networking and bonding going on. She now has the confidence and pride in herself to speak up in class. When another student said something incorrect, she*

was bursting, so excited that she knew the answer. (Mentor, speaking of a student mentee)

I'm struck by the mature tone of their language in these presentations. The students have a level of confidence, composure, and sophistication that I've rarely seen in other high school presentations. They have the museum's staff and scientists as powerful role models. (Researcher reviewing students' final projects)

- **Students become acculturated into a rigorous science environment** (e.g., in the research labs). They learned ways to navigate and maneuver through this type of environment, and grew in their abilities to interact with people and fit into the setting in appropriate ways.

The most important things that I learned are to be responsible and to work with other people. Those are important to me because I will need these elements to pursue my career and go to college. (Student)

The advice on networking and how to get started in research as an undergrad will help me build my resume and navigate my way through a relatively small field of science. The hands-on work was important in preparing me for my future and it taught me more patience. (Student)

This experience has been wonderful for [the student]. She has learned to balance schoolwork with the material presented here in an excellent manner. She has grown into a more mature student who appreciates knowledge for the sake of knowledge. I truly believe this experience helped her be accepted into Harvard. (Parent)

- **Students expanded their sense of their potential.**

He [the student] has focused his interests in science now on genetic research. This [program] actually affected his college choices in terms of a major. He is so far beyond my level right now, he teaches me! He has a goal of extending human life. He wants to try to help cure different diseases like cancer, heart disease and Alzheimer's. He spent a lot of time on this [the ITEST program], traveling two times a week on the bus and train from the Bronx. My son is lucky to be here. (Parent)

- **Students' enthusiasm for learning increased.**

> *She [the student] has a lot of pride in her work now. I'd sometimes get home from work at 2 or 3 in the morning and she was on the computer working. We're all proud of her [the whole family attending graduation]. This experience has been pivotal for her . . . she discovered what she is interested in and is excited about it. If you have a job that ties into your interest and you work hard, you have success. She went to the lab every day after school. Her mentor is here today too [at graduation] . . . we're all very proud of her. (Parent)*

- **Students better understood the relevance of science in their everyday life.**

Sixty eight percent of survey respondents said that they better understand the relevance of science to their life as a result of this program.

- **Students exhibited pride and honor about knowing their way around the museum**. They are given a special, staff-like badge which gives them admission to the museum through special entrances and to behind-the-scenes offices and labs through "staff-only" doors.

> *I got to meet scientists that I'd read about in my research papers! And we had the cool AMNH ID badge that no one else had. Meeting staff members from AMNH was great, and the actual hands-on research, amazing. We learned how to use [computer] programs that scientists use. This program offered many opportunities, everything that we couldn't do in school or even as a regular visitor to the museum. (Student)*

- **Students demonstrated an increased appreciation, understanding and respect for diverse cultures.**

> *I've met so many new people here. Kids from all different parts of the city . . . kids that I wouldn't have met [otherwise]. We get to know each other, and I realize, okay, they're a lot like me. We may dress different, or talk different, maybe our beliefs are different, but we get along. (Student)*

> *I noticed how the students are less reticent and more confident with themselves… especially interacting with others of various backgrounds. (Parent)*

- **Students learned how to be more responsible.**

  She (the student) made great friends and has become more responsible. She will be taking that experience with her to college. (Parent)

  He [the student] learned a lot that he can apply (especially working with others) in his future endeavors. He learned about commitment, leadership and working independently. (Parent)

  The dedication this took, of traveling to the museum and pursuing this program, has made him [the student] more responsible and confident. (Parent)

- **Students demonstrated the ability to learn from their failures and mistakes.**

  The biggest lesson for him [the student] was the fact that the data did not turn out the way he'd hoped it would [the hypothesis was not confirmed]. That was a big lesson for him. He learned from the negative results. (Parent)

  She [the student] came to understand and respect the scientific process more. I think she understands more about the time and effort involved, and sometimes the disappointment of the results . . . and how patience and accuracy of method are key. (Parent)

<u>**Skills**</u>

- **Students gained experience with and demonstrated improved skills utilizing a wide range of technologies** including:
  - using computers to enter and analyze data
  - using the Internet for scientific research
  - creating Power Point presentations and using projectors
  - using a Smart Board in the classroom
  - using a wide range of traditional and cutting-edge lab research equipment ranging from binocular and electron microscopes, calipers, and pipettes, to PCR machines, scientific calculators, and radio telescopes (see Technology Use section above).

- **Students' study skills and work habits improved**. For example, students learned how to manage their time better.

> *This experience taught him [the student] how to manage his time better. It was a huge time commitment . . . with all the travel and conflicts with other school related things . . . it was hard, but he got better at juggling everything. (Parent)*

- **Students demonstrated an increased ability to think critically and analytically.**

> *She [the student] has been prepared to do well at university in a research study. This experience has enriched her analytic and logic abilities. (Parent)*

> *This program has taught me to think clearly and rationally and to have an open mind when working on difficult problems. (Student)*

- **Students learned about and demonstrated scientific research skills:**
  - Conducting scientific observations
  - Generating research questions
  - Collecting data
  - Experimenting
  - Hypothesizing
  - Extrapolating
  - Drawing conclusions
  - Analyzing data
  - Recording information in science lab notebooks
  - Working with databases
  - Making tables and graphs to represent data
  - Using the library and Internet for research
  - Writing a scientific research paper (including abstracts and detailed bibliographies)

We asked participants in the end-of-program survey to rate the amount of experience they had with specific tasks related to conducting scientific research, and to also rate how confident they felt in carrying out such tasks. These tasks included such things **as conducting scientific observations, using a computer to analyze data, generating research questions, using the internet for research, and writing research papers**, to name a few. Based on the survey results, two tasks stand out as being particularly significant to the students. The first is conducting scientific observations. Ninety-three percent of participants said through the program they had had a great deal of experience with this task, and 79% reported feeling very confident in their ability to conduct scientific observations. Moreover, their experience level with this showed growth from the pre-test to the post-test: 77% reported in the pre-participation survey that they had experience in conducting scientific observations, compared with 93% in the end-of-program survey. In addition, 79% of survey respondents said they had spent a great deal of time generating research questions, and 74% reported feeling very confident in their ability to generate research questions.

> *Reviewing students' research papers – from first submission, through several iterations, to final submission – one can clearly see the exponential progress they made. There was significant growth in the focus of their research, and in their ability to write a scientific paper. (Researcher reviewing students' final projects)*
>
> *My research on flamingos has extended my knowledge. I feel more confident as far as composing ethnograms is concerned. (Student)*
>
> *The most important thing I learned is when I experienced being the researcher, actually doing research. It is important because I cannot experience it in other places. (Student)*

- **Students gained experience with and improved their communication skills:**
  - Giving oral presentations about their research or the research of others
  - Creating posters and Power Points to summarize their research
  - Presenting their posters and Power Points to the public
  - Interacting with each other, program staff and their mentors

Students were quick to point out that not only did they enjoy the social aspects of the program but those experiences helped them improve their communication and social skills. Meeting new people, having to work in teams, going on field trips together, all were highlighted as highlights of the program.

> *I think meeting new people and conducting and studying scientific observations and projects are the biggest highlights [of the program]. (Student)*
>
> *I think the program is the most valuable experience in my high school years. The first day I came, I was not expecting it to be as great as it is. I thought it was going to be just another extracurricular activity or an extra class to my day. However, what I got out of this program has gotten me more socially active and more familiar with the scientific process. (Student)*

Scientist Mentor Benefits and Impacts

Although not an explicit program goal, we found evidence that the program benefited and impacted the scientist mentors as well as the students. This is not surprising considering the amount of time that mentors spend with students and the overall quality of the program.

Mentoring is no easy task, and finding enough mentors can be difficult for program staff. Fortunately, through persistent hard work, the AMNH-ITEST program staff was successful at finding mentors (mostly from AMNH, occasionally from other local research institutions such as Rockefeller or Columbia) for what was generally one-on-one, or at times two-on-one, mentor-mentee situations.

The mentors dedicate considerable time during the school year to working with the high school students. In some cases a scientist mentor is head of a research lab or in charge of a scientific study with international complexity; or is a curator in charge of opening a new exhibit hall; or is a graduate student who is stretched thin and focused on completing a research project in order to complete their studies. They open their lab spaces and offices to these high school students once or twice a week and supervise them so that they can experience what it is like doing authentic research. There is no compensation for mentoring, and there is sometimes minimal institutional recognition. On occasion, the student doesn't work out. It can be a Herculean effort without many external rewards, but these scientist mentors do it anyway. Why? Although a variety of reasons come into play, most scientist mentors do it for altruistic motives. They want to give back. Somewhere along the way, someone mentored them. They believe passionately in education and in these kinds of hands-on educational experiences for young people. They know there is a growing need to prepare the next generation of research scientists and want to do their part.

Through the AMNH-ITEST program, there were a variety of mentor-mentee experiences; some more positive and productive than others. Overall though, the relationships and experiences were positive and mentors were most often willing to mentor again. More than the actual lab skills that students learned or research accomplished, mentors rated the relationship with the student as one of the most important aspects of the experience. It was through these relationships that mentors felt they made the most impact on students – serving as positive role models, putting a human face on scientific research, igniting the students' curiosity in the world and their passion for scientific endeavors, helping to build their self-confidence, and helping to expand the students' ideas of what they could do in the future. Mentors expressed pride in these accomplishments. For some, it fueled their own enthusiasm and inspired their work. Numerous times we heard mentors express appreciation for the youthful energy – for the inquiring minds, the comic relief, the innocent approach, and connection to contemporary culture – that students brought to their labs.

On occasion, students' lab work made notable contributions to the scientists' own research projects. As mentioned earlier, the research that students conduct in the labs during their second year mentorships is authentic, it is not simply contrived for the student's benefit. Data collected, observations made, and on occasion, discoveries made by the students are included in their mentor's published research.

Speaking about his student's lab work which ultimately contributed to a chapter in his dissertation , one mentor said:

> *Parasites on fruit bats is what he [the student] worked on specifically, looking at gene flow and population level genetics using a marker called CO-1, oh no B, it is mitochondrial gene…. He did a lot of extractions, DNA extractions, and so that involved working with an organism, pulling off a leg or two and then going through that whole process. (Mentor)*

More and more research grants require scientists to include an aspect of outreach in their work. Teaching and working with the public are forms of outreach. Through the AMNH-ITEST scientist mentors gain valuable teaching and mentoring experience, which some of them recognize and value highly.

> *I never had a mentor all the way through my early education. I wish I had. These kids are really lucky. And I've been lucky in the students that I've had. I learned a lot along the way about what it means to be a mentor. . . . This ties into what I have to do for my grant . . . part of the outreach component. (Mentor)*

> *I have been lucky to have had some teaching experience, but for people [mentors] that don't have teaching experience, it is a good way to get it, through this one-on-one mentoring. (Mentor)*

Some mentors do this as a way to give back to the museum. One mentor who started coming to the museum when he was young and went all the way through the after school programs offered, reflected that mentoring for this program was a way for him to come full circle, to help nurture new scientists within the institution that nurtured him.

> *I have been coming here since I was a kid. There, you can see a picture of me [standing in front of the museum as a child with his family]. I used to come here once a year with my parents, and because of coming here, I wanted to become a zoologist. This [the ITEST program] is a way for me to give back. (Mentor, Postdoctoral Fellow working in Ichthyology Department)*

Program Staff and Institutional (Museum) Benefits and Impacts

Lastly, (and again, not as an explicit goal but nonetheless an outcome of the program), AMNH-ITEST benefited staff and the institution as a whole.

On an individual level, we saw evidence of, for example, program staff learning from their experiences and improving their teaching skills. The AMNH-ITEST program and staff also benefited from being situated within the museum's education department which has many veteran educators and administrators who were able to lend support. ITEST program staff, whose primary background was in science, through support and coaching, as well as formative evaluation, increased their knowledge and understanding of pedagogical methods, and made strides in improving their teaching styles. For program staff with educational backgrounds, they gained firmer grounding in the sciences through the interactions with scientists and the plethora of interdisciplinary museum resources.

At a departmental level, we saw evidence that the ITEST program helped give continuity to the after school offerings for high school students. Museum staff were able to build on previous successful programs. Through external formative and summative evaluation, and internal assessments as part of a restructuring of the education department, staff refined and strategized their multiple offerings and found ways to institutionalize aspects of the ITEST program and incorporate it into their "life-long learning pipeline."

Looking for impacts of the ITEST program at an institutional level, we found ample evidence of both short-term and long-term benefits. Although perhaps more subtle and subjective than student and even staff benefits, these examples of ways in which the program helped the museum seem to us both notable and important.

When speaking with a group of ITEST scientist mentors, for example, they mentioned how because of this program there were increased inter-departmental communications and interactions. They bemoaned the fact that typically they were so busy and focused on their own work and departments, that they were unaware of what other departments were doing (education, exhibits, as well as other research labs). They were glad to have the opportunity to share with each other (about their research, about the ITEST students and mentoring, and about the museum as a whole), and there was consensus that they benefited from these interactions. Along the same lines, through the ITEST program, research departments developed and maintained connections to other educational and industry-related research facilities (e.g., Sloan-Kettering, Columbia, Pfizer, etc.). Thus, the program provides professional networking opportunities to scientist mentors and possibilities for future collaborations.

The museum benefited directly from the ITEST program in that one of the program staff, with a strong genetics background as well as experience with education, helped design the new Sackler Educational Laboratory – an exceptional classroom space attached to the new Hall of Human Origins which ITEST students used from time to time. That is just one of the symbiotic opportunities we are aware of that was made possible by the presence of ITEST program staff in the museum. Then there is the general 'badge of honor' or 'feather in the cap' of having a National Science Foundation-funded grant (ITEST) which is an asset for the museum and might help attract other funders.

Deanna Banks Beane wrote about the benefits not only to teens from these types of programs, but also for the museums:

> *A good after-school program is more than just a place dedicated to enrichment and learning. It is a place for finding friends and acceptance, a place where competence and confidence are built, a place where children's dreams are developed and nurtured. Science centers that support such youthful transformations not only benefit from the positive energy of young people, but also achieve an enhanced role in their communities, and nurture a citizenry that values the presence of informal learning institutions.* (After-School Hours: A Time for Children and Science Centers, ASTC Dimensions, November/December, 2000.)

The ITEST program helps the American Museum of Natural History meet its mission of serving the local community. The regular presence and active engagement of local students helps the museum be more ethnically and socio-economically diverse, more reflective of the community. The fact that the majority of program participants are female helps the museum do its part to foster more gender equity in the next generation of scientists. As the aforementioned benefit for scientists in their labs, students' presence in the museum also infuses the place with increased energy, enthusiasm, and optimism and hope for the future which reinvigorates and revitalizes. Students bring their parents, families, and friends to the museum, bringing yet greater diversity to the museum. These encounters could well cultivate long-term supporters. Lastly, this type of high-quality, in-depth program for high school students not only fits the institution's mission and modus operandi, it is also good for its public image. As confirmed in our interviews with parents and teachers of ITEST students, it increases the community's respect and appreciation for the museum.

Program Evolution, Challenges and Opportunities

Program evolution and progress

As evaluators, we have seen the AMNH after school programs for teens evolve over the past decade and follow the natural institutional ebb and flow accompanied by upper-level leadership changes and staff turnover. However, the core vision of these programs has remained constant, and we see evidence – through recent reorganization within the education department, increased leadership, coordination and articulation of educational programs – that the investment AMNH is making in these programs is enhancing, expanding, and institutionalizing the work of ITEST and their other outreach programs.

Increased communication around and consideration of the work of the mentors in this program, along with the program's place in the bigger strategic scheme of the AMNH educational programs are additional signs of progress. Our recent interviews with staff revealed that ITEST is nested within a "pipeline" vision for educational programs at AMNH. The staff sees the program as an integral part of a cohesive set of entry points for youth from K-5 through middle school, high school, and undergraduate years. Former student Debbie Perez is one example of this pipeline vision in action. (See her case study vignette in the Appendix.) A continued and concerted effort to bridge the various outreach programs and increase the communications and coordination among them will result in more success stories like Debbie's.

Recruitment

One modification staff made to the ITEST program is that they now primarily recruit through the after school programs, instead of going directly to schools to recruit or targeting specific demographics. This method of recruitment has its pros and cons. It is too soon to tell, but over time we wonder if it might result in less student diversity as only the ones who by chance become aware of the program and self-select to participate become involved. With this new recruitment method, students can pick and choose classes from a variety of topics for the first year; thus, there is not one consistent cohort going through all the genetics classes together, for example. There is also a shift away from an emphasis on students having to prove themselves initially. The application process in the beginning of the first year is not as extensive as in previous years. Students do have to apply during the second summer to go on to the research year. One result is more committed students for the second year, but a disadvantage is less group identity going into the second year.

In the original ITEST proposal, AMNH planned to specifically target the physically challenged through this program. Although some effort was made, major obstacles having to do mostly with transportation and expense prevented that goal from being realized. In keeping with the museum's goal of targeting the underserved with these programs, we encourage AMNH to continue to invest in the effort of reaching out to schools and populations of students who otherwise would not have these types of opportunities or might not even become aware of them on their own. Reflecting the challenge of balancing all these shifting dynamics and goals, one staff member articulated, "Access is important, and blending is important also . . . having advantaged and disadvantaged students blended in a program. Our mission is to graduate top science students . . . the smartest, most committed, motivated students, not just the elite."

Documentation

One very concrete contribution of this ITEST program to the ongoing outreach programs at AMNH is documentation. ITEST program staff developed a syllabus for the genetics classes which will be a useful resource for future instructors. As part of the ITEST grant, staff are also developing a "Guide" to designing and implementing this type of program. The intention is that this Guide will be a resource for other institutions and organizations wishing to offer similar programs for youth. Along the lines of documentation, we encourage

AMNH staff to continue to improve ongoing systems for documentation of the program– its students (e.g., contact information, demographics, attendance), the mentors, alumni, and other museum and outside contacts as resources for the program.

Mentors

One of the most powerful and impactful components of the program is also, not surprisingly, one of the most challenging – the mentorships. Recruiting enough scientist mentors, training and supporting them and the students, and getting the scientists to mentor again are all challenges that the AMNH staff face. Having one-on-one or two-on-one student/mentor relationships contributes immensely to the students' experiences. There are approximately 200 scientists and 300 graduate students and post docs at AMNH, but finding enough mentors for this program remains a huge challenge. People's time is limited, and there is sometimes resistance to the idea. For the current size of the program, there is need for 10-12 mentors per year. Program staff are drawing on many of the same scientists who mentored in the past and had overall positive experiences, but it is difficult to bring on new ones.

As we stated in previous reports, "For these types of mentorships to be the most effective, mentors need to be carefully cultivated and recruited, expectations on both sides need to be clear and frequently communicated, and mentors need to be offered ongoing support and opportunities for reflection. All this takes time and concerted effort on the part of program staff; something that should be accounted for when designing and implementing the youth programs."

Program staff made strides throughout the ITEST program in expanding connections with museum scientists, propagating potential new mentors, and in preparing students well for their research work (thereby improving the chance that mentors will have positive experiences). There is also renewed conviction among staff that the whole system of working with mentors needs careful design and implementation. We encourage staff to continue creating and testing structures and systems for mentor recruitment, training, communication of program information (i.e., goals, expectations, and responsibilities), ongoing communication and support for the mentors and students, and providing opportunities for mentors to share and reflect with staff, and with each other, about their experiences. Providing structured ways for mentors to stay in touch with former students or to hear about what they have gone on to do is another way to keep mentors invested in the process and willing to participate.

The Education Department staff expressed a desire to seek grants to conduct research on the mentor component of the program, as well as to collect longitudinal data on graduates. We encourage them to pursue these ideas and believe that this research would add greatly to the field's knowledge about these types of in-depth programs.

Program staff – structuring internal supports

> *Continuity is difficult [with staff turnover]. We need to create strategic, sustainable structures. (Program staff)*

As we emphasized in previous reports, the work of the program leader is crucial to the success of the program. Because of this, program leaders need to be supported within the larger department and institution. They need to have a structure by which they themselves can reflect on their program and practice, on their relationship with the students and mentors, and on the program as a whole. They need to be evaluated and offered professional development that can assist them to better draw on their strengths and improve on areas of weakness.

Program staff need both scientific as well as education expertise. We think that having a program leader who is a scientist can work well, as long as the museum, again, provides enough key support and professional development so that the students are not only learning science content, but are also nurtured in the program. Conversely, having a lead person who is more of an educator can also work well, as long as that person has sufficient support and structure to draw on the plentiful scientific resources of the museum.

Creating more synergistic opportunities

From our perspective, there are opportunities throughout the two-year program to involve a wider range of people as a way to enhance and promote the program. For example, alumni students could be more proactively kept in touch with and invited back on a regular basis to assist with classes, field trips, and to give special talks on lessons they have learned about college and career preparation. Parents, school teachers, and community members could be invited to special events such as documentary screenings, lectures, or student/mentor presentations. Perhaps students could be invited to various department meetings within the museum to talk about their research experience. This would not only be a good experience for the students, but it would be a way to help develop awareness and interest in the program and possibly help propagate new mentors. Because the students and their stories are often compelling, conceivably students could be highlighted in newsletters or be invited to give special presentations at museum fundraising events. Again, this would be a learning experience for the students and help further public awareness and support of such programs.

Successfully integrating the museum in every aspect of this program is something to continually strive for. Coordinating all these programs and synergies is a huge challenge, but overall, the AMNH staff has made considerable progress in drawing upon the wealth of resources at hand and in creating a well thought-through, viable, and successful program.

Conclusion

The American Museum of Natural History, through its ITEST program, offers a high quality, and highly unique in-depth research experience for high school students from underserved populations. As an informal science education institution, AMNH's research and education efforts are connected, thus the setting is a prime opportunity for this type of program. The museum is internationally renowned for its collections and contributions to understandings of many sciences including genetics, biosystematics, taxonomy, and astrophysics. Its resources in this regard seem endless. As one mentor put it, "There's always some place you haven't been in the museum." The access to these collections and to cutting edge approaches of scientific study makes the nature of the student experience rich and unique. Additionally, state of the art research facilities allow second-year students who are well-prepared to participate in a mentorship and engage in activities typically reserved for upper division or graduate level college students.

We found the AMNH-ITEST program to have successfully met its goals of helping students gain experience with technology, develop specific scientific research skills, learn science concepts, and increase their awareness and commitment to STEM career paths. The program exceeded these goals by drawing upon prior work and becoming more institutionalized. In addition, we detected ways in which the AMNH-ITEST program benefited program-providers, i.e., program staff, scientist mentors, and the museum in general.

Students from a wide range of socio-economic, ethnic, cultural backgrounds, and learning styles benefited in multiple ways (awareness, knowledge and understanding; engagement and interest; attitudes and behaviors; skills). We found that by drawing on the uniqueness and wealth of the museum's resources, the program proved not only deeply enriching for students, but in some cases transformative.

The documented design features and lessons-learned from this program will hopefully inform the field; help other informal science institutions who wish to serve their local high school students in in-depth, experience-based ways; and ultimately, help increase the number and quality of students pursuing STEM careers.

APPENDIX A

Four Case Study Vignettes of AMNH-ITEST Students

In constructing these vignette(s), we have been struck by the power, passion and poignancy of the students' voices in the data we have gathered and analyzed. The following vignettes highlight various aspects of the potentially profound benefits of the program for students that we highlighted in this report.

Female Student Empowered by AMNH Astrophysics Program

The student described in this vignette is an 11th grade student who began participating in the Hayden Astrophysics program, part of the AMNH-ITEST program, when she was in 7th grade. Her parents are immigrants from Mexico and she describes her neighborhood as a place where there are not a lot of opportunities or good examples for young people. Before she began the program she was interested in social studies and improving her English and had thought of becoming a teacher or a lawyer. Her middle school offered few opportunities to study science and for this reason she signed up for the program at AMNH. After a few years in the program, she realized that she really enjoyed math and science and chose a high school that emphasizes math and science. After two years in the astrophysics branch of ITEST, she thinks she may want to pursue a career in astrophysics or astronomy.

> *I remember I wanted to be a teacher, or a lawyer, but now that I am into this [AMNH program], maybe I will pursue a career in astrophysics or astronomy. I really do like that. What we are doing right now, it is like more real time, like an astrophysicist, we are using IDL [a type of computer program] as if we were really, really astrophysicists. It is really interesting and it is not something that I have to say, "Here we go again". There is a chance I might go into that field.*

She describes the time and attention given to her by the museum staff, including her research mentor, and explains that she learns well at the museum because of the efforts the staff takes to make sure she thoroughly understands the material.

> *You can't stop unless you solve the problem. Otherwise our teachers will send you to think about it, to ask questions. They always tell us "If you don't get something, ask questions, ask questions, that is the way to learn."*

As a result, she has gone from not knowing about astrophysics to being able to describe complex theories, analyze data from satellites and help install a radio telescope. She describes the impact this learning has on her experience at school.

> *I was in the 9th grade and we were already learning about Planck's constant [at the museum] and this year [11th grade] in my physics class the teacher talked about it, and I actually knew what he was talking about. I saw other people around me struggling—"What are you saying, what is this?" I had an idea of what it was, so it was a bit easier for me to understand it. Also, the teacher will*

> *talk about supernova's or something and he will ask the class if somebody knows about them and he is surprised that I know the answer. He actually asked me, "How come you know all of this?" I told him I was in a program at the museum and he was really shocked, he said "Oh wow. I can't believe there are still students out there that do such things." The feeling of it is wonderful.*

She describes these benefits extending beyond physics to her computer programming and math classes where skills and knowledge she has learned at the museum transfer into her work in these classes and knows that they will give her an advantage when she enters college.

Beyond the obvious impact on her math and science capacities, the experiences she's had at the museum have given this student great confidence in her abilities and a sense of pride in her accomplishments.

> *It gives you this feeling that you are not down there where everybody expects, especially for me, a Hispanic person coming from immigrant parents. They expect me to drop out of high school, because that is what a lot of people are doing, they are dropping out of high school and getting pregnant. Just the fact that I'm doing this, I feel like I can make it out there in the world.*

Her parents have supported and encouraged her participation in the program and share her sense of pride. Her younger brother is now in the program and she gave him the following advice.

> *At first it is kind of hard because they teach you all of this hard stuff and you think "I can't do this, I can't do this, it is too much for me, I am not ready for this." But as time passes by, you realize that you are capable, and that is one of the things that this program helps you with a lot, realizing that you are capable of doing something, you are capable of succeeding. If there is an obstacle and if there is a problem that you can't solve, there is a way for you to get the answer.*

She summarized her experience by saying:

> *It has been amazing. A life changing experience. I feel like I am somebody. I would probably be home watching TV if it wasn't for this program.*

Dedicated Student Musician Expands His Horizons

The student described in this vignette is a 12th grade student who began participating in the Genetics program, part of the AMNH-ITEST program, when he was in 11th grade. His family is from New York and he has lived in New York most of his life. He travels more than an hour each way to get to the museum twice a week and attends a school in Queens that was constructed for 2,000 students but has over 5,000 students attending. He plays in the school's jazz band and practices guitar five to six hours a day. He has always had an interest in science and grew up visiting the dinosaur collections at AMNH. He credits his interest in science in part to his grandfather who is a self-taught engineer. He is planning to go to college to pursue a degree in chemical engineering.

He enrolled in the Genetics program, with encouragement from his family, because of his strong interest in science and because he believed that his participation in a program at a "world renowned" museum would increase his chances of getting into a good college. As the program progressed, he also expressed enthusiasm for the opportunity to do an independent project and to get a chance to spend time in a research laboratory, something he had never done before.

> *If I take up the career of chemical engineering, it will be great preparation. It will show me what I am going to be doing, help me find my way around the lab, show me how things work.*

After he completed his research project, a study of morphological diversity in cichlids[19] in eastern Africa, he described the time in the lab as the most valuable to him because he felt it was very applicable to his future.

> *It gave me a good feel for what it is going to be like in a laboratory. This is the type of pace you go. . . It [the ITEST program] is pretty much two years of learning something that you would never learn in high school or maybe even college. It is giving you a taste of what a career in this field would be like. It really helps you, and it gives you an idea of what is to come, like the type of work, so you can see if you actually want to do it or not.*

[19] Cichlids are a fish from the family Cichlidae. The diversity of cichlids in the African lakes is important for the study of evolutionary speciation.

As part of his independent research project, he also had the challenging experience of writing a research paper—his first.

> *I had to do a scientific paper at the end, it was pretty much teaching us how to write scientifically. It was difficult, especially since, the way the reports are put together, they are very fact, fact, fact, straightforward. And the way I am used to writing is very talkative.*

The student also described how the combination of challenging coursework and small class size offered by the museum program allowed him to learn much more about Genetics than he would have on his own or at school.

> *It helped me understand a lot about things I'd been wondering, like how DNA actually really works. I'd always heard DNA is the building blocks of life, but I wondered how it works, and eventually I was able to learn that through this program.*

Furthermore, the student described how just being at the museum – and having special access to behind-the-scenes collections, etc. – was inspirational and increased his awareness of and interest in other areas of scientific research.

> *I visited their collection of fish, which is incredible! It is practically four warehouse floors of just fish. I think they said it is either second or fourth biggest collection of fish in the world, but the biggest collection of indexed species. Have you heard that story from a couple of years ago where this woman is swimming off the beach in Brazil and found this prehistoric fish which they haven't seen in thousands of years? They have that fish in the museum on the second floor. It is right there in a huge tank! There's just so much [at the museum] that I wouldn't otherwise see in my life. It made fish biology much more interesting to me.*

"It's all about saying I can."

Life-Changing Experiences: How the Museum's After School Program Served as a Stimulating Refuge for a Young Man

The young African-American man described in this vignette began participating in the AMNH Hayden Astrophysics program when he was in 7th grade, and as part of the ITEST program during his last two years as a junior and senior in high school. With very challenging family and living conditions at home, the museum became a safe, comfortable home-away-from-home for him. He serves as a paid intern for the astrophysics program and helps the instructors prepare materials for the courses.

Living and going to school in the Bronx, he travels an hour and 45 minutes each way to and from the museum a few days each. His mother originally piqued his interest in science when he was a young boy by teaching him chemistry and physics through everyday life experiences such as cooking. Thus, he has always liked science and gladly enrolled in the Astrophysics program at the encouragement of his science teacher. As a result of participation in the program, he feels that not only does he still like science, but he understands it better, and that overall, he feels well-prepared academically.

> *The program has taught me so much about physics, it's not even funny. Now I can pretty much answer any question that my science teacher gives us . . .physics, biology, math. I'm excelling in classes at school, and it's affecting my grades. Before, I couldn't have even passed physics, but do now! Also my memory is better. I didn't realize I could hold so much in this little brain. I'm learning how to look at things, analyze them, and remember them. It's amazing.*

He enthusiastically described how his learning continues to deepen in a current AMNH-ITEST course.

> *Now we are learning a lot about IDL [visual data-analysis software], about programming, about Goshen curves, about astronomical bodies that emit radio wave emissions and radiation, and we graph that. It is really challenging, we haven't been exposed to it before.*

Talking about the abundance and quality of high-tech equipment they have available for students to use, he explained,

> *Since I am an intern, I have to set up and put away computers, projectors and all kinds of gadgets. I learn a lot. We even got to help install a radio telescope . . .we learn a lot about how it works, how not to break it, and what you have to do to keep it working*

As the student described his final research project, *Understanding the Basic Characteristics of Quasars*, it was evident that he is gaining a further understanding of sophisticated astrophysical concepts and tools through this program at the museum. He described how he uses data from the SDSS website[20] to analyze spectral data and optical images of quasars. He also described how working on his project with his mentor is giving him the opportunity to learn the more general skill of problem solving.

> *I have learned a lot about solving problems. Every day, our mentor, he gives us a problem and we have to solve it. Why isn't this working? Why do we have this, giving us so much radiation? Why can't we…? Why can't we just look at it, and we can't see the radiation coming to us, why this, why that? It is really amazing how we get it and we answer the questions, but it takes a long time to answer the questions because they are really large processes.*

What stands out for this young man about this program, in addition to the rich and in-depth learning experiences he is having, is the willingness of extremely busy research scientists to work with students on their research projects and coursework.

> *What stands out is about the availability of our mentors. When I was working on our project, it took literally less than a day for our mentor to email us back saying yes, you can come up to the astrophysics department and we can help work on it. That actually amazed me because I know he is a very busy man yet he takes lots of time to devote to us, as do all of the other [program] staff.*

[20] Sloan Digital Sky Survey is a survey that maps one-quarter of the entire sky, determining the positions and absolute brightness of more than 100 million celestial objects. Data is available online.

The student also recognized that the program has helped him to develop inner capacities of open-mindedness, curiosity, and understanding—qualities sure to serve him well in all aspects of his life.

> *[Without this program] I would be more judgmental and a little bit more ignorant. I wouldn't be understanding as much in my life. It has taught me to open my mind to more things, to be open-minded literally, to understand that people are different and it doesn't matter if they are different. . . . I'm more interested in looking up at the sky, and we [he and his godmother who he lives with] want to get a telescope. And I look at more scientific shows on TV than I would have otherwise. I never did that before! I'm currently taking TIME magazine, reading a lot about history, politics . . . a lot about science, religion, and ethics.*

Confirming staff's observation that this student has grown profoundly in a many ways, especially in self-confidence and leadership, we recently learned that he applied to and was accepted at Carnegie Mellon University. The student summarized his feelings about the program.

> *The program here has been incredible. It's been amazing for me. Basically it's a program about the sciences that teaches students how to think, how to think outside of the box, to prepare them for college, to prepare them for life, and also helping them in school. It helps them stay out of trouble, and gives them a second home in a way. I've made a lot of friends here, all ages, and that's a great thing. I can't tell you what it's meant to me.*

"It is <u>really</u> hard, so <u>that's</u> exciting!"

The Thrill of Challenge: An AMNH Pipeline Success Story

Now a college junior attending Stevens Institute of Technology majoring in Chemical Biology and working simultaneously under the supervision of Dr. Diana Weber at the Sackler Institute for Comparative Genomics at the American Museum of Natural History (AMNH), Debbie Perez began her work with the High School Research Academy at the AMNH in 2003 as a high school sophomore. When she applied, Debbie didn't think she had a chance to get into the ASCEND[21] Genetics program and was excited about her new after school opportunity.

> *High school was not challenging for me and it was kind of boring. I didn't really want to go home at the end of the day … so I applied to this program. I found it to be interesting and I took it seriously.*

At the time, the program represented much more to Debbie than simply something to do after school. It was an intellectual home and a safe haven in which the shape of her future would begin to take form. During her years in the high school program she ended up coming more often than was required and immersed herself in the work and the environment.

> *Coming here was like a sanctuary in a way because of things going on in my family and my life and I just wanted to get away, in a good way, so, drown myself in productiveness and not narcotics or anything bad. I want to be different and a lot of kids try to be different by trying to be cooler than other things, but I want to be different by I guess maybe being smarter… being above the norm, I guess.*

This first year did, in fact, challenge Debbie and she thrived on the challenge.

> *It was kind of cool to have something tough, you know. We had college material and it was exciting. It was all chemistry-based and I liked*

[21] ASCEND was a previous iteration of AMNH's in-depth after school science programs for high school students, upon which the ITEST program was built.

chemistry a lot. Chemistry class was a bit easy in high school. . . . It [the AMNH program] was challenging because we had a lot of exams and studying and learning about genetics…it was kind of cool to have something tough, you know. I really enjoyed working with DNA, because I couldn't see DNA, it was exciting to be able to have blind faith and see it on a gel … working with something that is microscopic.

In her second year of the program Debbie was paired with Dr. Diana Weber in a research mentor/mentee relationship. Dr. Weber was and still is a role model for Debbie. From being introduced to scientific literature to working with new technologies like DGGE (Denaturing Gradient Gel Electrophoresis), Debbie's mentor has played a critical role in what Debbie can imagine for her own work and future.

I have a very interesting advisor that I work with, Diana. She is really passionate about her work. She likes what she does and every time I have a question, she will answer it to the best of her ability. She is always available, nice, and she is the one that really got me interested because she makes it interesting for me and exciting. She game me so many things to read! … I had never read a scientific paper. [They] are so dense that I remember first reading them and I didn't understand it. My main goal was to try to understand papers like that, because they seem interesting and I want to know what is going on.

After graduating from the program, Debbie missed the research and her work at AMNH.

When I graduated from the ASCEND genetics program, I graduated from high school as well and so I went into college the next year and I really didn't do much research, but I missed it.

So, Debbie contacted Diana to see if she could volunteer in her lab, which she did. She came two or three times a week, whenever she could despite her tough course load. This work paid off; at the end of her freshman year in college Debbie was awarded an REU (Research Experiences for Undergraduates) at the Mote Marine Laboratory in Sarasota, Florida. She talked about the surprise awaiting her advisor there, who thought Debbie was a college senior.

They didn't have to train me for anything because I knew everything and so I just went through the project without difficulty… They didn't realize I was a *freshman, they thought I was a senior! My advisor there asked me 'Where are you applying to graduate school?'. I said, 'I have three more years to do that, I am a freshman.'*

Reflecting on how the work has changed over time, Debbie relates learning about cutting-edge techniques along with lifelong lessons she has learned in her work at AMNH.

The lab grows in that it adopts new technologies like the DGGE, we have a new machine. It is complicated, we are still working on it and trying to figure out what we can do with it. It is really hard, so that is exciting. Basically, it is the techniques that really stay the same or you adopt better ones, and the projects are what change. … I have had many laboratory experience and I have matured a lot. My vocabulary has expanded. I have a lot of patience. You need a lot of patience when you are in the lab because you can't give up. There are so many things that bog you down because some things don't work, but you always try and try again and you have to optimize a lot – get temperatures and protocols to work together in order to make something work-- and that has taught me a lot, to be very patient and consistent and keep going. I have also learned to be patient with people as well. There are a lot of us working in the lab. I also learned to respect my elders and people who have more experience.

Little did she know, the dedication and drive that Debbie demonstrated would carry her through several years of lab-bench research at the AMNH, for which she is now being paid, and open what appear to be an infinite number of opportunities for her. The initial rigorous science course experience and an ongoing collaborative relationship with Dr. Diana Weber, all housed in an intellectual home for a budding scientist, the American Museum of Natural History, have been instrumental in helping to shape Debbie Perez's future.

My main goal is to be a professor. I feel, in high school, I had some pretty good teachers, but in college I had the worse professors and I really want to be a profession so I can help students understand things better.

When the idea of being a professor at a "Research I" institution was suggested, where she could teach AND do research, Debbie said,

That would be great!