National Human Genome Research Institute

Background Paper on Human Genome Education at the Pre-College Level

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Introduction

This report will discuss human genome project education primarily at the pre-college level. Access to professional development, instrumentation, commercially available classroom kits, print lessons and/or texts, and Internet access have served as avenues and/or bottlenecks to implementation of human genome education in schools.

Courses

Specialized high schools and science centers around the country as well as some private and innovative "regular" high schools have been offering programs in biotechnology since the mid-1980s. That is around the time that the official announcement of a human genome project was made in 1985. Biotechnology and genome education may be taught as individual lessons, units, special projects or in-school field trips, and even semester, yearlong and multi-year programs.

Since the 1970's, high school courses in human genetics have been offered as biology level 2 electives. Most of the laboratory activities prior to the mid-1990s did not require technical instrumentation. Students might conduct a profile of their own and classmates' genetic traits such as ear curling, ability to taste PTC, tongue rolling or eye color. They'd use peanuts, plants or flies to generate data for Punnett squares and gene frequency analysis, draw pedigrees, and make karyotypes from paper copies of Turner's, Klinefelter's and normal male and female chromosome spreads turned into letter-sized reprints. Human blood-typing was effectively abolished in the mid-1980s due to fear of HIV and hepatitis transmission. Kits using sheep's blood or even chemical simulations were marketed as substitutes.

Middle schools are slowly beginning to offer courses in biotechnology and forensics, and a number currently offer units in these topics as more kits are becoming available and teachers are getting professional development through university and medical, school-sponsored programs. Students are fascinated with crime and solutions so this is viewed as a good "hook" to engage students who would not necessarily be in honors classes to become more interested and knowledgeable in science.

Delta Education [ecustomer.delta-education.com] and 4H [national4-hheadquarters.gov] have widely disseminated curricula in biotechnology that contain and/or can be adapted for human genome project education at the middle school level.

Bioethics: Low-cost Teaching and Learning Opportunities

As the Human Genome Project (HGP) began to take shape, with its specified support for ethical, legal and social issues via National Institutes of Health (NIH) funding and parallel funding via the Department of Energy (DOE), the Biological Sciences Study Curriculum (BSCS) provided one of the most widely used print resource guides on ethical issues for high school. The genome project enabled and encouraged life science teachers to teach, for the first time, about the values and social implications of science and to provide opportunities for students to engage in role-play and debates in science class. "The Case of Nathaniel Wu," which describes a young man who may have inherited the Huntington's chorea gene, was published in a BSCS curricular monograph in 1991, yet is still visited in biology classes at the high school and college levels 10 years later.

Though the vast majority of schools still do not have access to instrumentation for biotechnology, teachers can nonetheless teach aspects of biotechnology and the genome project, specifically bioethics. Students could engage in actual discussions of the genome project and its implications. Kansas University Medical College offered one of the earliest and most popular professional development programs for pre-college teachers with its focus on bioethics. Laboratory-based professional development institutes throughout the country incorporate training in teaching bioethics to complement the lab-learning.

Instrumentation and Classroom Kits

In its early days, the HGP became possible because of the ability to clone and sequence segments of chromosomes. Teachers in schools with access to instrumentation focused lessons, labs and units on the construction and analysis of recombinant DNA molecules. They used instruments (gel boxes, power supplied pipettors) that were made available through partnerships with local industries that supplied used equipment, technical visitors or use of space for field trips. Students who learned about the methods and applications of DNA biotechnology through antibiotic gene transfer experiments in bacteria became prepared to learn about applications of these processes to study of the human genome, though for the first few years, hands-on work focused on antibiotic gene transfer. By the late 1980s, several companies, including Carolina Biological Supply Company (marketing lab activities developed by Cold Spring Harbor), Bio-Rad, and Edvotek produced and marketed kits and instruments for conducting hands-on classroom work in biotechnology. Carolina, Wards, Sargent-Welch and Fisher had been the major supplier of genetics lab materials until then.

Cold Spring Harbor was probably the first institution to offer widely disseminated professional development and learning opportunities in biotechnology, and then the technology of human genome research. Through its on-site programs on Long Island and the traveling VectorVan, personnel from what is now the Dolan DNA Learning Center at Cold Spring Harbor visited sites all over the United States to train teachers in DNA technology and provide a framework for schools and school districts to obtain needed instrumentation and expertise for learning about recombinant DNA technology. *Recombinant DNA: a Short Course* (by Watson, Tooze and Kurtz, 1984) was probably the first widely recognized text to be used at the pre-college level. Drlica's shorter and smaller *Understanding DNA and Gene Cloning* addressed many of the same topics but was not as widely known. The DNA Learning Center published several editions of its *Laboratory DNA Science* lab book; with input from many teachers it provided the most comprehensive text and lab manual available for quite some time. The newest editions are used at both the high school and college levels.

However, access to instrumentation continues to be problematic. Juniata College had pioneered mobile laboratory semi-trailers to transport sophisticated instrumentation for high school chemistry classes in the late 1980s. The Cold Spring Harbor Vector Van could supply a classroom set of gel boxes, pipettors, Petri Plates etc. The Fred Hutchinson Cancer Research Center, Virginia Tech and other universities have provided equipment on loan through trunks that teachers could pick up themselves (urban areas) or have shipped statewide (rural and urban areas) since the mid

1990's. Slowly but surely, teachers are convincing their school district administrators to invest in biotechnology equipment. One important impetus is the inclusion of molecular biology (genetic transformation) as a required laboratory activity in the College Board sponsored advanced placement biology.

By the mid-1990s classroom kits for chromosome polymorphisms became available; even high school students could perform PCR with specialized primers to detect Alu, D 1S80 (*sic*), and other variable tandem repeat genes. Private schools and schools with access to university/industry partnerships and equipment loans have taken great advantage of this opportunity.

One of the best examples of educator-scientist partnerships with a focus on the HGP has been the High School Human Genome Project offered through the University of Washington. Sequencing is complicated at its best, so the program is designed to train scientist and teacher teams together. The scientist provides the expertise in running large gel electrophoresis units and, with the teachers, provides a multi-day unit on conducting the actual sequencing in a high school classroom.

Print and Video Resources

Pre-college teachers have long been "tied" to texts as the foundation of their course syllabi and daily curriculum. Kruezer and Massey (KM) wrote the first text to address teachers in own realm, though pioneers in pre-college biotechnology have continued to also use the wet-lab oriented CSHL publication, *Laboratory DNA Science*. Though the CSHL book is the best in terms of providing students opportunities to conduct real science work, the KM book has text, concept activities and paper labs in addition to wet labs.

Monographs on the topic of the human genome have proved popular in schools as well. Because of how they have been funded, these monographs have been made available to a wide audience. The BSCS guides on the HGP, biotechnology etc., have been mailed to high school teachers who are members of professional associations such as the National Association of Biology Teachers. Private foundations, such as Howard Hughes Medical Institute, published excellent, four-color booklets on specific topics related to the genome project, for example, "Blazing a Genetic Trail" and "The Genes We Share with Yeast, Worms, Flies and Mice." In the past few years, the NIH Office of Science Education has developed its own curricula and/or funded organizations such as BSCS to produce high quality curricular monographs on the genome project that are available free by request. The recent video, Web site and teaching guide on the genome project, produced at National Human Genome Research Institute (NHGRI) was a big hit with life science teachers as well.

Your World magazine, a publication of the Pennsylvania State Biotechnology Association addresses human genome issues in several editions. Teachers in urban school districts as well as rural districts find this a helpful supplement for their middle school students. The Biotechnology Institute [biotechinstitute.org] now distributes the magazine.

TV/Video projects are popular with teachers as well. Teachers like these because they can assign them as creative homework for students (most students watch TV anyway) if the show is scheduled within the time period of the appropriate unit, or because many school district library systems purchase the video and/or get download permission for taping. Students like visual learning and showing a segment diversifies the typical science lesson. Commercial movies such as "The Race for the Double Helix" and especially "Lorenzo's Oil" stimulate student interest in the human genome.

Bioinformatics

Schools began to gain access to the Internet in the early 1990s. Database technology for use by research scientists was rapidly evolving at the same time. By 1996, Medline and GenBank were beginning to appear on the horizons of teachers at schools with Internet access, but the process was as cumbersome for teachers as for researchers. The

appearance and redevelopment of PubMed, the National Center for Biotechnology Informatics (NCBI) and PDB offered access in schools to the identical data and software available to scientists. By the late 1990s, teachers were learning about sequence analysis at national and state teachers conferences. Access Excellence, which was privately funded through the Genentech Education Foundation, trained a corps of teacher leaders to become savvy with computers and provided Internet access so they could share their newly gained knowledge with each other and provide Internet and other science training to colleagues in their localities. The high quality of server-side software such as BLAST and small footprint client-side applications such as Rasmol, CHIME and Cn3D are helping teachers and their students gain access to the same research data as scientists.

The Center for Image Processing in Education is an outgrowth of Robert Greenberg's (planetary science) math teacher training program to use the computer for mathematics. The recent curriculum package, Biotechnologist [cipe.com], utilizes the small application NIH Image and specially collected pedagogical data sets so that teachers and students can learn to analyze restriction digests and sequencing gels, chromosome spreads and electron micrographs.

Web sites such as Biology Place [biology.com] (which requires a paid subscription) are, nonetheless, becoming popular with teachers since the site is updated frequently and has a minimum of "link rot," links that have become outdated or are no longer supported on their home servers. Teachers still have very little time, few computers and only intermittent Internet access, though access and stability are both improving.

Student interests:

Middle school and young high school students (life science is frequently the first high school science course students take) are naturally interested with their own bodies, voice concern about their personal health, and are fascinated by how crimes are solved using DNA technology.

Professional Development Pioneers (current contacts are listed)

1. Kansas University Medical Center [kumc.edu]
   Contact: Debra Collins
   Funded initially through the National Science Foundation (NSF) [nsf.gov]

2. Cold Spring Harbor DNA Learning Center [vector.cshl.org]
   Contact: David Micklos

3. University of Washington High School Human Genome Project [chroma.mbt.washington.edu] and satellite programs
   Contact: Maureen Munn

4. Access Excellence [accessexcellence.org]
   Contact: Vivian Lee Ward

5. Woodrow Wilson Teacher Leadership Institute and TORCH satellite programs [woodrow.org]
   The 2001 summer institute was focused on the Human Genome Project.

6. CityLab at Boston University Medical School [bumc.bu.edu]
   Contact: Don DeRosa
   Funded initially through an NIH ADAMHA SEPA grant. Provides teacher training and use of facilities for classroom field trips. Bus converted to laboratory provides mobile setting for onsite school field trips. Satellites

in several states including Connecticut and North Carolina. See the human genome related lab "Amp Up Your DNA."

7. Biological Sciences Curriculum Study(BSCS) [bscs.org]
   Contact: Mark Bloom. Middle school.

8. Washington University in St. Louis. Modern Genetics for All Students [so.wustl.edu]
   Contact: Sarah Elgin

U.S. Department of Energy. Daniel Drell
Human Genome Project Information [ornl.gov]
Genomics and Its Impact on Medicine and Society: A Primer [ornl.gov]
To Know Ourselves [ornl.gov]
Your Genes, Your Choices [ornl.gov]

NIH Office of Science Education. Bruce Fuchs
Curriculum Supplement Series [science-education.nih.gov]

National Human Genome Research Institute
NHGRI Web Site
Genome.gov Online Research Resources
Genetics Education Kit [hhmi.org] (Funded in part through HHMI)

About the Author, Toby M. Horn:
Dr. Horn earned an A.B. in Chemistry from Bryn Mawr College, Bryn Mawr, Pa., and a Ph.D. in MCD Biology at the University of Colorado, Boulder. After a six-year stint as a staff fellow at the National Cancer Institute (NCI), Dr. Horn became a high school teacher, co-developing three levels of biotechnology courses at Thomas Jefferson High School for Science and Technology in Alexandria, Va. For 9^{th} graders, the course was a six-week, laboratory-learning unit in biotechnology basics (microbiology, cell culture, biochemistry), supplemented the standard introductory biology course, and was one of five technologies that students experienced on a rotational basis. A high school juniors and seniors, TJ pioneered a semester-long DNA Biotechnology course at around the same time that CSHL was developing its Learning Center in 1987 and hosted a one-week workshop for the D.C. metropolitan area. A semester-long independent laboratory research course was developed for seniors. As one of the NIH satellites for the University of Washington (UW) High School Human Genome Project, and with support of the Department of Energy, Dr. Horn's course offered a semester-long senior laboratory in human genome sequencing using primers provided by UW.

Additionally, in 1988-89, a student mentorship program was developed with placements at government, museum, university and private research labs. Currently more than 40 students a year work in outside laboratories. Horn wrote the safety monograph, "Working with Bacteria and DNA in Pre-College Science Classrooms," published in 1992 by the National Association of Biology Teachers.