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bio-itest

new frontiers in bioinformatics and computational biology

Y3 Final Report

Northwest Association for Biomedical Research

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Innovative Technology Experiences for Students and Teachers
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Bio-ITEST: New Frontiers in Bioinformatics and Computational Biology

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Overview

Bio-ITEST: *New Frontiers in Bioinformatics and Computational Biology* is funded by the National Science Foundation's Innovative Technology Experiences for Students and Teachers (ITEST) program, and is designed to bring the exciting discipline of bioinformatics to high school teachers and students. In addition to curriculum development and professional development, Bio-ITEST includes a strong career component for students, exposing them to a number of different science, technology, engineering, and mathematics (STEM) careers. Bio-ITEST is a model designed to provide secondary science teachers with the knowledge, skills, and resource materials to engage their students in the newly developing fields at this intersection of biology and information technology, ensuring that students will be able to participate in these important new workforce areas. The long-term goals of our work are to increase teacher and student understanding of bioinformatics and the ethical issues related to the acquisition and use of biological information, while increasing the number of students interested in bioinformatics and related STEM careers, with particular emphasis on students from underserved populations.

In our third and final year, we concluded our research study evaluating the effectiveness of our professional development and curricular efforts in increasing teacher and student understanding of bioinformatics and related STEM careers, as well as our exploratory study on the emerging role of science teachers in fostering student career awareness. Students in classes of Bio-ITEST teachers engaged in authentic research projects, developing testable hypotheses and exploring issues in their communities using DNA barcoding and bioinformatics tools. In addition to the 42 teachers who participated in our professional development workshops, 10 students took part in our first summer course for students. The Introductory and Advanced bioinformatics curricula were finalized after extensive field testing and feedback from teachers, students and scientist, and the program is actively engaged in publishing our program findings in a number of scholarly journals.

Goals and Objectives

The Bio-ITEST program has the following goals and objectives:

- Increase student and teacher understanding of bioinformatics and the ethical issues related to the acquisition and use of biological information.
    - Develop and adapt introductory and advanced bioinformatics curriculum units.
    - Provide teacher professional development workshops.
    - Build an active and engaged online community for teachers.

  - Disseminate materials through the internet and science teacher conferences.
- Increase the number of high school students who are interested in bioinformatics and related STEM careers, with particular emphasis on students from underserved populations.
  - Support mentorship and authentic research opportunities for students.
  - Provide opportunities for teachers and career counselors to learn more about bioinformatics and related STEM careers.
  - Through collaborative relationships with programs serving underserved STEM students, facilitate the participation of underserved students in Bio-ITEST programs.

Increasing Awareness of Bioinformatics and Related Careers: Research Study of Program Impacts on Teachers and Students

The focus of the research study included the following questions:

- Does the Bio-ITEST program increase participating teachers' knowledge and perceptions of bioinformatics and related STEM careers?
- Does the Bio-ITEST program increase participating students' knowledge and perceptions of bioinformatics and related STEM careers?

Impacts were measured using survey questions that were classified as representing one of four **career constructs**, based on a literature scan on the cognitive-behavioral building blocks of career development.[1]

Table 1: Cognitive-Behavioral Building Blocks of Career Development

Construct	Definition and Rationale
Awareness (A)	**Expanding career awareness** Students develop an understanding and appreciation of a variety of STEM careers (e.g., knowledge of required skills, education, work/life issues).
Relevance (R)	**Seeing the relevance of the subject matter to their lives** Students find the content meaningful (e.g., relevant to everyday experiences or decisions they may need to consider in the future).
Engagement (E)	**Engaging with the subject matter and STEM careers** Students show interest in learning and experiencing more (e.g., active participation in discussions, asking questions that go beyond the content presented).
Self-efficacy (SE)	**Feeling comfortable using the tools of science** Students develop a sense of self-efficacy in approaching scientific tasks and mastery of tools employed by real scientists.

Teacher results are based on surveys tracking growth over three points in time: at the beginning (baseline, "Pre") and end of the 2010 Summer Bio-ITEST Professional Development

[1] Further detail on these constructs can be found on the NWABR website at nwabr.org/about-nwabr/publications. "Literature Scan: Student Awareness and Career Motivation in the STEM Fields."

Workshop (August 2010, "Post") and at the end of the school year (May-June 2011, "End-of-Year" or "EOY"). Survey findings for teachers are shown below in **Figure 1**.

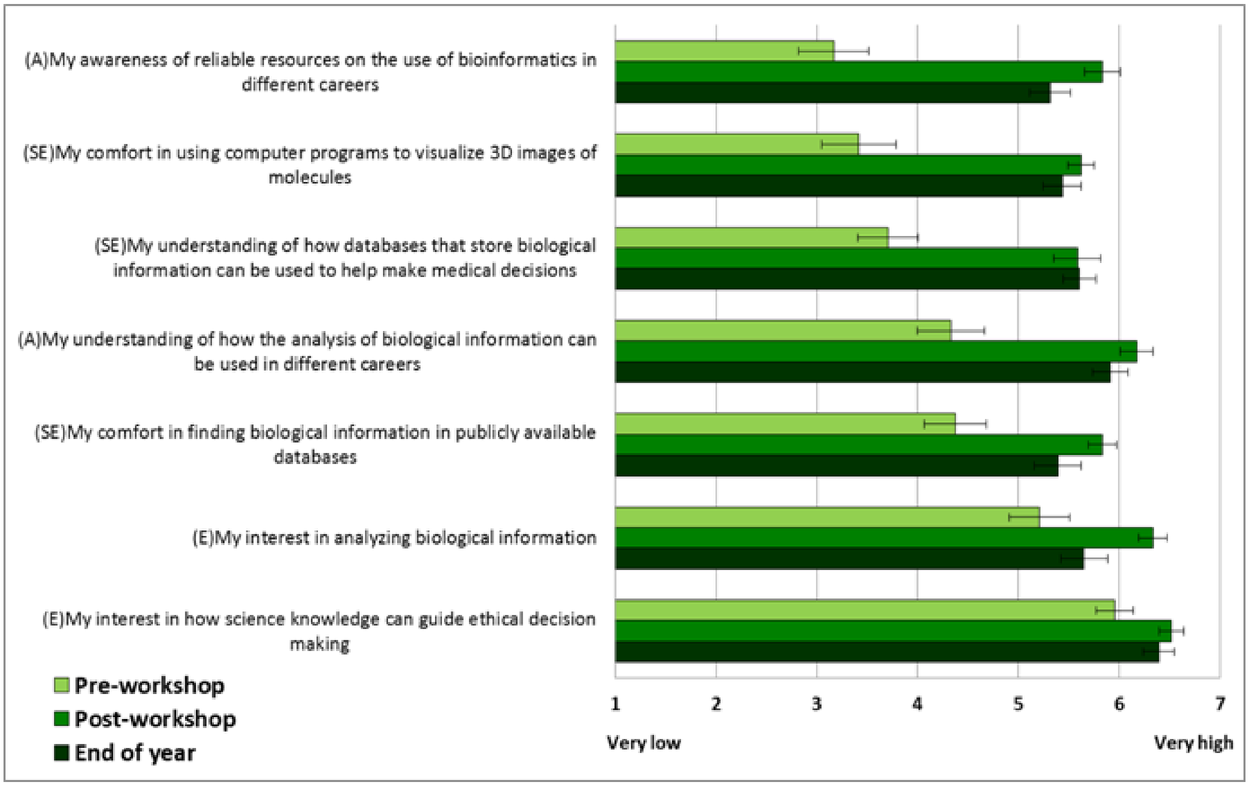

Figure 1: Teachers demonstrate significant gains on all survey items following the 2010 Professional Development Workshop. When compared to responses to survey questions on the Pre-Workshop survey (N=24), teachers showed significant increases Post-Workshop (N=24) and at the End of the academic year ("End of year," N=23) in three conceptual areas: A = Career Awareness; E = Engagement; SE = Self-efficacy. Survey items are arranged in the order of pre-workshop response means, as less change is possible for higher pre-workshop responses. Bars represent standard error of the mean.

All pre-/post-workshop gains were statistically significant ($p < 0.05$ is the criterion for all significance tests). The conceptual category for each survey question is contained in parentheses, corresponding to the table above. The largest gains were for Career Awareness and Self-efficacy items.

Compared to baseline, teachers largely sustained these gains throughout the school year. All pre-workshop/end-of-year gains were statistically significant except "My interest in analyzing biological information."

Teachers also completed a set of retrospective items on the post-workshop and end-of-year surveys. Ratings are shown in Figure 2. The conceptual category for each item is the same as those found above. Teachers rated themselves "before" (retrospectively) and "now," post-workshop and at end-of-year. **All self-reported gains at both times were statistically significant. The largest gains overall were reported for Self-efficacy items.**

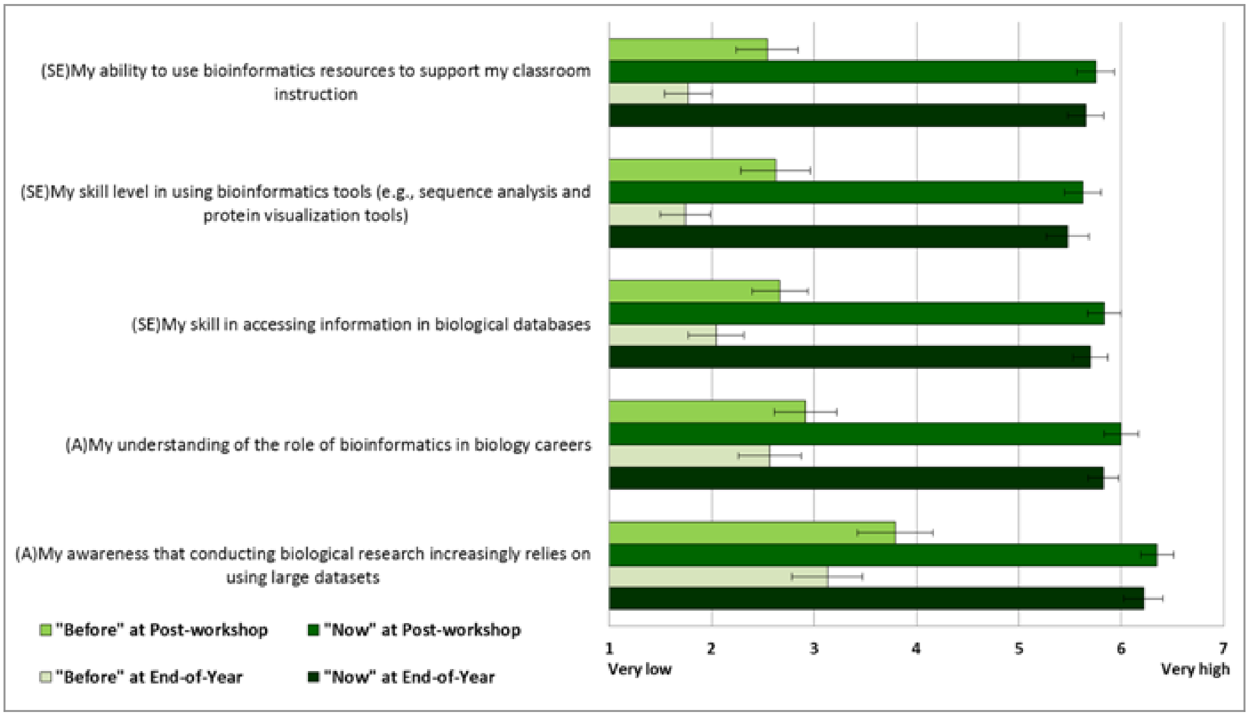

Figure 2: Teachers demonstrate significant gains on retrospective all survey items following the 2010 Professional Development Workshop ("Post-Workshop," N=24) and at the end of the 2010-2011 academic year ("End of year," N=23). Responses are categorized into two conceptual areas: A = Career Awareness and SE = Self-efficacy. Survey items are arranged in the order of pre-workshop response means, as less change is possible for higher pre-workshop responses. Bars represent standard error of the mean.

"I think these types of programs are very valuable both to students' education as well as to teachers. The skills and exposure to careers and advanced topics is something that I feel is missing from many secondary school courses. I appreciate that topics I learned about in college are being made accessible to high school students and being tied in with career applications."

Students of participating teachers (N=12) who taught the Introductory unit, *Using Bioinformatics: Genetic Testing*, completed pre- and post-unit surveys and returned consent forms to participate in our research study. Of the 699 students in the 28 classrooms of these 12 teachers, 374 (54%) students consented to take part in the Bio-ITEST study, and 289 (41%) completed pre-unit and post-unit surveys measuring conceptual constructs similar to those measured for their teachers. Characteristics of student participants are shown in Table 2.

Table 2: Characteristics of Student Participants

Curriculum Unit:	Introductory	Advanced
Number of Students	289	41
Gender	63% female 37% male	56% female 44% male
Ethnicity	66% non-Hispanic white 33% Hispanic 1% unknown	78% non-Hispanic white 22% Hispanic
Grade Level	18% freshman (51) 33% sophomores (95) 25% juniors (73) 24% seniors (69)	0% freshman (0) 2% sophomores (1) 32% juniors (13) 63% seniors (26) 2% unknown (1)

The student pre- and post-unit surveys also measured the four conceptual categories that constitute key career development building blocks. A multi-level modeling approach was used that controlled for the effects of student grouping within classrooms and within teachers. Figure 3 shows the raw (unadjusted) item means. All significance tests used the criterion of $p \leq 0.05$.

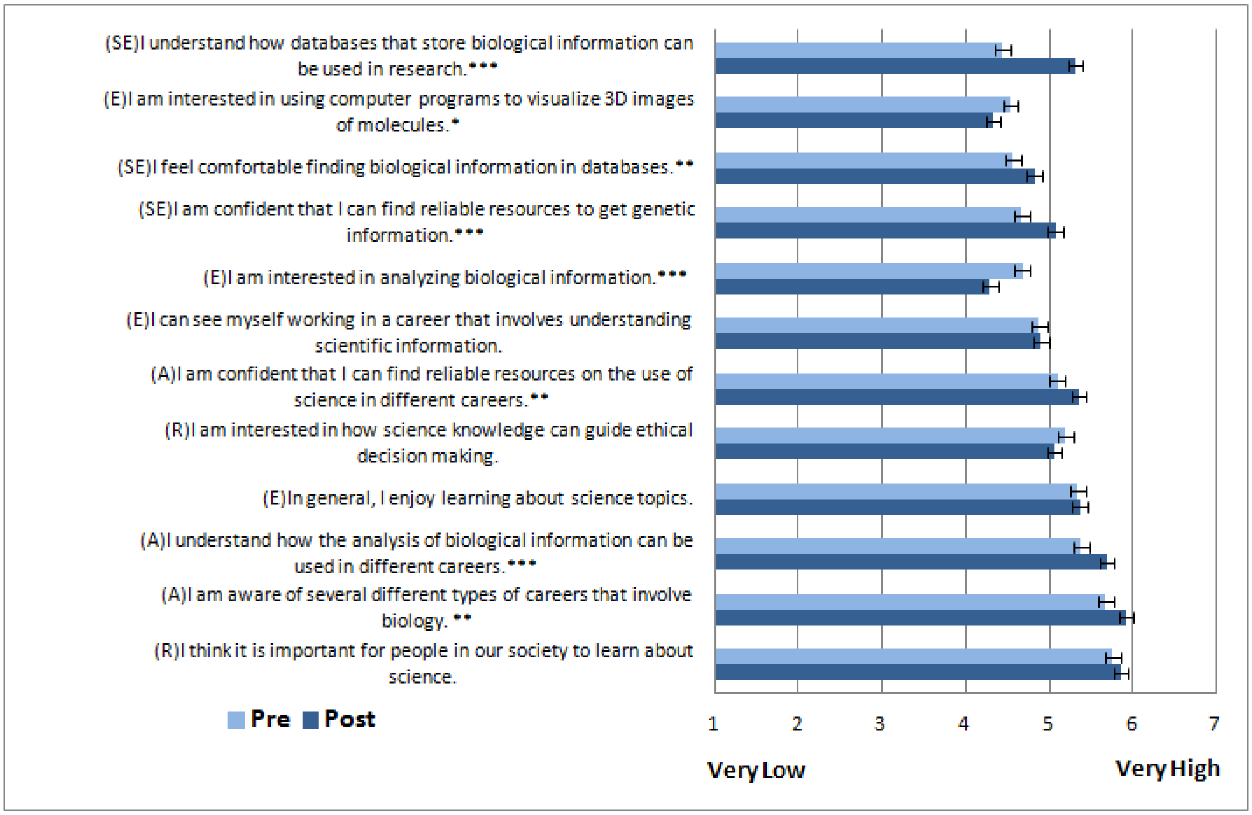

Figure 3: Students demonstrate significant gains on pre/post survey items measuring career Awareness and Self-efficacy following instruction with the Introductory bioinformatics unit on genetic testing. A = Awareness, E = Engagement, R = Relevance and SE = Self-efficacy. Survey items arranged in the order of pre-unit response means, as less change is possible for higher pre-workshop responses. Changes are statistically significant as follows: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. Bars represent standard error of the mean. N=289

Students made significant positive pre-/post-unit gains on items measuring Awareness and Self-efficacy. Changes were generally modest, less than 0.5 on the 7-point scale. However, this level of improvement in Awareness and Self-efficacy was impressive given the short duration of the curriculum intervention (5-7 lessons taught over 1-2 weeks).

Neither of the pre-/post- changes on the two Relevance items was significant. Two of the four pre-/post- changes on the Engagement items were significant and negative. These declines were modest, less than 0.5 on the 7-point scale.

"The lessons on ethical issues and awareness of the different careers that use bioinformatics had the most impact. Understanding how technology has changed science and how many different career options there are in biology. I have had many students tell me "I didn't know I could do this in science" - it really is an open ended, making connections "real" curriculum."

"It opened up a whole world to them - they knew nothing about the topic before. Now they understand and can use some bioinformatics tools, and they have a clear understanding that there are jobs available in this area, as well as some knowledge about the types of jobs, and the education required to get them."

On post-unit retrospective questions measuring Self-efficacy, Awareness and Relevance, , students showed strong positive gains from "before this unit" compared to "now" (Figure 4). Mean student gains ranged from 2 to 3 points on a 7-point scale.

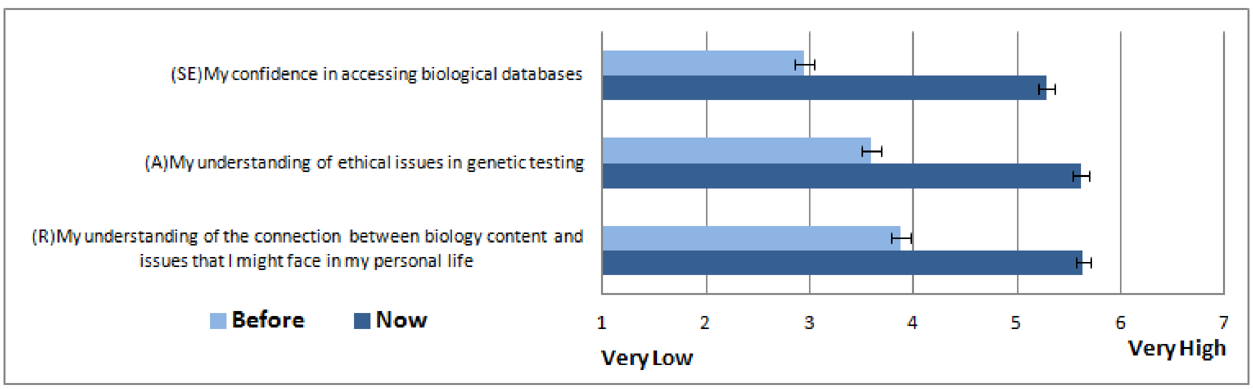

Figure 4: Students demonstrate significant gains on retrospective survey items measuring Self-efficacy, career Awareness, and Relevance following instruction with the Introductory bioinformatics unit on genetic testing. Items arranged in the order of "Before this unit" response means, as less change is possible for higher "before" responses. All changes are statistically significant at p <0.001. Bars represent standard error of the mean. N=289

A separate post-unit survey was also administered to the 41 students (N=41) in 3 classes that participated in the Advanced unit, *Using Bioinformatics: Genetic Research*. Characteristics of student participants are also shown in Table 2 above. **Student post-unit retrospective mean ratings comparing "before this unit" to "now" showed significant gains on all items, ranging from 1.1 to 3.1 on the 7-point scale (Figure 5).**

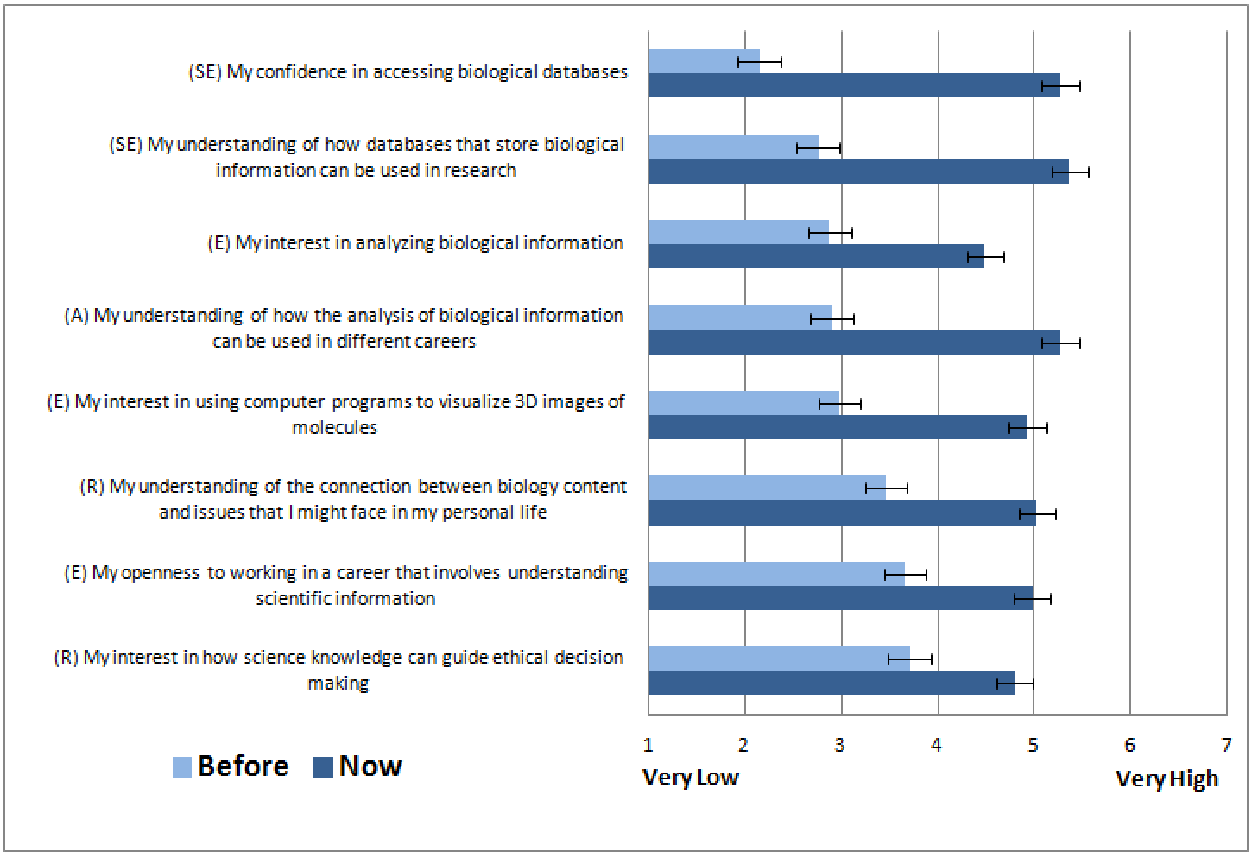

Figure 5: Students demonstrate significant gains on all retrospective survey items measuring following instruction with the Advanced bioinformatics unit on genetic research. Items arranged in the order of "Before this unit" response means, as less change is possible for higher "before" responses. All changes are statistically significant at $p < 0.001$. Bars represent standard error of the mean. N=41.

The Advanced student survey also included an opportunity for open-ended responses about students' own experiences with the Bio-ITEST curriculum, and what was their most significant "take-away" lesson.

"I had no idea that the general public has access to all of these databases and information."

"It opened a door that I could go through, it introduced me into something I might be interested in."

"There are many ways to help people besides being a doctor."

"It created a new possible job career. I love science and I never knew much about this type of science and it is very fascinating."

"It makes me much more interested in biology and working with different organisms."

"Careers in science look more desirable than they did before, as now they are better explained, and show how there are some alternate methods in doing all of these jobs. They don't seem as tedious or difficult with the added features from bioinformatics."

The Emerging Role of Science Teachers in Facilitating STEM Career Awareness

The National Science Foundation's Innovative Technology Experiences for Students and Teachers (ITEST) grants seek "solutions to help ensure the breadth and depth of the STEM [science, technology, engineering, mathematics] workforce." The program probes questions such as: "What does it take to effectively interest and prepare students to participate in the science, technology, engineering, and mathematics (STEM) workforce of the future?"[2]

A recent review of literature concludes that "high school appears to be a key point at which young people's impressions of science influence their future career decisions."[3] However, just at the critical juncture for making career decisions, high school students face multiple challenges, including lack of clear and timely guidance, in planning their careers.[4] As one interviewee noted:

"The best career counselor is the science teacher— they have daily contact, understand the kids, know what they know and need, and can differentially raise awareness in the classroom."

This investigation used a case study approach and was conducted over an 18-month period in 2010 and 2011, relying on data collected through qualitative interviews and focus groups. We identified a purposeful sample of 20 science and career educators, including teacher participants from the Bio-ITEST workshops, and other key informants involved in teacher education, workforce development agencies, and science education initiatives.

A summary of our findings is presented below, and will be submitted for publication in appropriate science education forums in 2012.

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[2] National Science Foundation (April 21, 2011). Innovative Technology Experiences for Students and Teachers (ITEST). Retrieved August 18, 2010, from http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5467

[3] Subotnik, R.F., Tai, R.H., & Rickoff, R. (2010). Specialized public high schools of science, mathematics, and technology and the STEM pipeline: what do we know now and what will we know in 5 years? *Roeper Review, 32*(1), 7-16.

[4] For example, see the following: Johnson, J., et. al., Why Guidance Counseling Needs to Change. *Educational Leadership* v. 67 no. 7 (April 2010) p. 74-9; or Reese, S. A Leading Role for Career Guidance Counselors. *Techniques* (Association for Career and Technical Education) v. 85 no. 7 (October 2010) p. 16-19.

How Do Science Teachers Perceive their Roles in Fostering STEM Career Motivation?

An important underlying question in this investigation is whether, and in what ways, science teachers view developing STEM career awareness as part of their job. Teachers commented that student acquisition of science career information is "random" at best. In some school districts, budget cuts have eliminated or scaled back funding for career counselors who have traditionally provided students with occupational information. When asked where students get information on preparing for science careers, one teacher noted:

"I think they get it in a hodgepodge of places, they don't know where to go. . . . I am struggling with knowing where to send them. They get it from TV and commercials. We used to have an amazing career center on our campus and two great staff, but due to budget cuts it is closed. We have no career counselor. There is no place to get brochures, no one to talk to. If they go online and plug in "biotech," they get two million hits and that is not helpful."

Our interviewees were asked to describe views of their own roles in fostering STEM career motivation. We heard a wide range of responses: for some the idea of deliberately supporting student career awareness was new, or they expressed the view that high school seemed "way too early" for a student to be thinking about a career; while others were already "on-board" in integrating career-rich activities into their lessons. One respondent reflecting on teachers' roles in career awareness said:

"A disservice we do as teachers is that we haven't really thought about it. But I get emails all the time from kids saying, 'I went into global health because of what I learned in your class. . . .' We haven't given ourselves enough credit for our influence."

Even many educators who did infuse career awareness into their lessons said that they had not received preparation to do so in their teacher education programs, that their knowledge of careers was limited, and that they didn't have time to add in any topic that wasn't part of preparation for mandated end-of-year exams.

Teaching Strategies that Promote Career Awareness

Although the interviewees described a diverse range of strategies, an analysis of the interviewees' comments revealed four promising approaches for successfully raising science career awareness (Table 3).

Table 3: Approaches for Raising Science Career Awareness in the Classroom

Approach	***Rationale***
Incorporate both formal and informal approaches	Students benefit from multiple paths of exposure to science careers. Teachers recommended infusing career awareness constantly, and not just as a separate unit. *Each Bio-ITEST lesson features a different career, in addition to culminating career lessons with vocational skills development in each unit.*
Help students see scientists as real people	One insight that echoed throughout the interviews was that many students don't envision themselves as scientists, in part because they don't see scientists as "real people." Formal and informal opportunities to connect with scientists can help students recognize that they are "regular people" who have hobbies, families and outside interests. *Bio-ITEST career interviews explore both professional and personal topics, including family and hobbies.*
Connect the dots	Interviewees emphasized that teachers need to make explicit connections for students. Several used the term "connect the dots" to describe this practice. One educator said that exposure alone to career information does not necessarily translate into career motivation. Teachers must explicitly make connections between lessons and career skills. A related activity includes embedding real-world assignments into the curriculum, such as creating a resume, or "applying" for a job. *Careers featured in Bio-ITEST lessons tie directly to lesson content, and show how science is used or done. Students also learn how to develop a resume and cover letter when applying for a job.*
Embed reflection	Reflection leverages long-term impacts from discrete science lesson experiences. One key informant pointed out that even a powerful event like a science career fair can be forgotten if students don't think deeply about what they learned. Reflective activities included journaling, responding to structured papers, and class discussions. *Every Bio-ITEST lesson ends with an opportunity for guided student reflection about lesson content and remaining questions.*

A paper summarizing examples of replicable career-infusing strategies shared by Bio-ITEST teachers will be submitted for publication in a practitioner journal in spring 2012.

Challenges and Solutions to Infusing Career Information into the Science Classroom

While science teachers play a key role in promoting STEM career awareness among students, a number of challenges exist to their ability to fulfill this need.

Teacher Knowledge of Science Careers

"If I don't understand how fields of STEM merge together, I am reticent to encourage kids in careers."

"It would be cool to know what those different fields are, and I could say, that is what a biostatistician would do."

"Instructors need experiences in business and industry in the summer time; they need to be in the real world themselves."

Bio-ITEST teacher professional development workshops include tours of local research institutions, guest speakers and panel discussions with scientists, and hands-on experiences where teachers can use the tools of science.

Classroom Resources

"I need help with navigating the Web. It is a nightmare. I need help getting pointed in the right direction, and being able to decipher good resources from trash."

Teacher requests for classroom materials and support included:

- Accessible curriculum materials that teachers can pull out and use as needed, such as lessons that highlight the "career of the day"; and PowerPoint slides, video clips, or interviews that profile people in different science careers, including scientists from underrepresented populations.

- Access to diverse speakers who know how to speak effectively to an audience of high school science students and technical support for communicating with scientists electronically.

The Bio-ITEST Introductory and Advanced curricula have been developed in partnership with teachers, scientists, bioethicists, and curriculum development professionals. Each lesson includes a detailed, easy-to-follow Procedures section, student handouts, and PowerPoint slides featuring a "Career in the Spotlight."

The NWABR Speakers Bureau provides a connection between the scientific community and the general public and features research scientists sharing the latest developments in their field and talking about career opportunities.

<u>**Implications for Policy and Practice**</u>

Equity: Raising Career Awareness for All Students. Science teachers have the potential to play a particularly significant role in raising career awareness for students from populations underrepresented in STEM careers. While not all high school students have access to career counselors, or the social networks that may expose them to career opportunities, all are in contact with at least one science teacher. Furthermore, classroom teachers are uniquely positioned to connect with students regularly, and in a variety of formal and informal ways. Our findings suggest that it may be particularly important to focus on policies that infuse career lessons into all introductory-level biology classes in order to reach students from populations underrepresented in the sciences, and who may enroll only in those courses.

State and District-Level Policymaking Opportunities. Interviewees noted that state and district-level policy changes could support STEM career awareness, such as inclusion of STEM career awareness in state science standards. Several of the teachers said that career awareness is not accorded much weight in the Washington state standards. One teacher noted that textbook selection is a district-level decision, and a district could choose to make inclusion of career lessons a criterion for textbook adoption. Certain science textbooks are known for their exemplary incorporation of career lessons.

Strengthening Pre-Service Education and Ongoing Teacher Professional Development. Pre-service education and ongoing professional development experiences can encourage teachers to infuse career awareness into curriculum. Pre-service education may be most significant, as this is where norms around teacher expectations are developed. In one focus group, the entire group of over 20 teachers unanimously exclaimed that instruction relating to careers had never been addressed in their pre-service preparation. In Washington, an understanding of science careers isn't required for a biology endorsement. Including a science research practicum as part of a pre-service requirement could strengthen the confidence of teachers as they talk about science careers.

Students as Citizen Scientists: Authentic Research Using DNA Barcoding

A key element of the Bio-ITEST program is the incorporation of an authentic bioinformatics research project into the curricular materials. Engaging students in real-world research projects is a proven strategy to encourage interest in science careers (O'Neill and Barton, 2005). Researchers who have investigated student motivation (Csikszentmihalyi, M. and Schneider, B., 2000), have found that the most effective way to motivate students and prepare them for the labor force is to provide them with perspectives that integrate scientific content with the social and global contexts in which science occurs, and to foster values and attitudes that promote desire for challenges. Schneider et. al (1995) have also found that students who report high motivation and challenge in their schoolwork are more likely to invest in future educational opportunities.

Barcoding Background

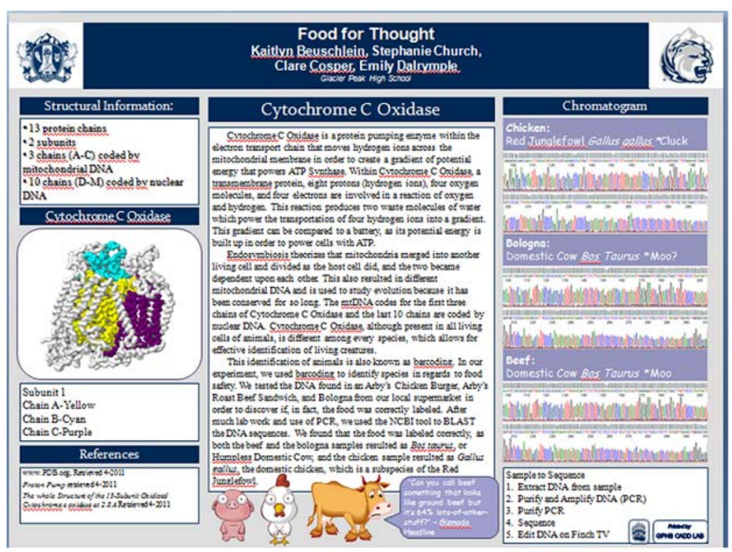
DNA barcoding is a taxonomic method that uses a short genetic marker in an organism's DNA to identify it as belonging to a particular species. For animals, scientists use the cytochrome c oxidase subunit 1 (*COI*) gene, encoded by the mitochondrial DNA. For plants, two genes are used: the gene encoding the large subunit of rubisco (*rbcL*) and MaturaseK (*matK*), both encoded by the chloroplast DNA. Barcoding can be used to catalog and confirm the discovery of a new species, or to identify the species of an unknown sample. DNA barcoding offers exciting opportunities for students to engage in authentic research, generate testable hypotheses, and learn how to use the tools of science. Since the first published reports of "sushigate," when two Trinity High School students from New York City cataloged extensive mislabeling of fish served in local restaurants, barcoding has continue to gain in popularity for use in education settings.

DNA barcoding is a technique with several advantages for student projects. Since the *COI* gene is mitochondrial, the DNA is more abundant and less prone to degradation. The region that is sequenced is short, eliminating the need to generate several overlapping sequences and assemble them. Mitochondrial DNA lacks introns in many organisms, which also simplifies the analysis. In addition, DNA barcoding provides concrete connections for students between DNA sequences and the surrounding world.

Barcoding Experiments in Bio-ITEST Classrooms

During Y3 of our project, a number of Bio-ITEST teachers have used DNA barcoding in their classes with supplies, reagents, and laboratory protocols provided by our program. Ms. Caraballo's students showcased their DNA barcoding projects at NWABR's 2011 Student Biotech Expo.

- *Bologna & Taco Bell Meat*
  At Glacier Peak High School, Ms. Caraballo's students confirmed that bologna from their local grocery store was indeed *Bos Taurus* (beef), while the true identity of the Taco Bell meat tested remains a mystery.



- *Mosquito Identification*
  While purifying DNA from mosquitoes collected from their school campus to determine if the species that can carry malaria exist in Washington, DNA sequencing results returned on *COI* data from *Homo sapiens.* Was this a contaminant from their DNA purification, or had this mosquito just feasted on human blood?

- *Mislabeled Fish*
  At Monroe High School, Ms. Foote-Wenz's students were concerned with issues of conservation. Reports of mislabeled seafood in supermarkets and Asian grocery stores abound, but without conclusive evidence, it is challenging to determine if there has been any

wrongdoing. Her students purified and sequenced DNA from fish samples from a well-known Asian market in the area, and were disturbed when the sequence data revealed that the fish were not only protected, but endangered. However, given the problems with the students' experimental controls, Ms. Foote-Wenz advised caution in interpreting their results. Dr. Perry's students at Lakeside School had similar problems with their experimental controls during their DNA barcoding of squid from local restaurants.

Stay tuned for more DNA barcoding results from the front lines of Washington's High Schools. These students and teachers vow to repeat these experiments after solving the problems with the controls so that they can make conclusions about their data and share their findings with others in their communities.

Partnership with the Seattle Aquarium: Identifying Optimal Genetic Markers

New Bio-ITEST project partners for our DNA barcoding project extend the potential for classroom use of DNA barcoding. The Seattle Aquarium has provided a number of biopsy samples from sixgill and sevengill sharks, giant squid, Pacific octopus, and a number of fish species from the Puget Sound. Dr. Shawn Larson, Curator of Conservation Research and Animal Health Coordinator at the Seattle Aquarium, inspired a number of Bio-ITEST teachers with her guest speaker presentation at the previous two-week professional development workshop held in August 2010. Students of 2010 teachers, teacher participants at the 2011 summer workshop, and student interns working with Bio-ITEST project staff are barcoding these samples for the Aquarium, and comparing the data generated on species and sequence diversity with data collected using another genetic marker, the D-loop of the mitochondrial DNA. This data will assist Seattle Aquarium researchers in knowing which genetic markers are best to use in different situations, with significant implications for conservation efforts, while showing students the types of scientific questions that can be answered with using bioinformatics.

Partnership with NOAA: Sea Snail Identification

Bio-ITEST has also grown their partnership with researchers at the National Oceanographic and Atmospheric Association (NOAA), who have also provided samples for DNA barcoding. One project, currently being undertaken by Ms. Mueller's class at Seattle Academy, involves identifying large sea snails caught in drag nets off the Alaskan coast. These snails, measuring over three inches in length, are difficult for scientists to identify morphologically as the constant movement of the oceans currents and waves slowly wear the ridges on their shells that make field identification possible. Ms. Mueller's students will test with DNA barcoding whether or not the morphological identifications by scientists match the DNA sequence data, and how this might vary by geographic location and water depth at the collection sites.

For students without access to wet labs in their classrooms, high school interns working with Bio-ITEST staff in the Student Training Lab of the Fred Hutchinson Cancer Research Center are purifying and sequencing DNA from Seattle Aquarium and NOAA samples, which will be posted to the Bio-ITEST website for students to analyze. In the spirit of scientific collaboration, made possible by advances in information technology, student scientists need not be in the lab to contribute to the scientific endeavor.

Reaching Students Directly:
"Dynamic DNA: Exploring Biological Systems" Summer Course

Collaboration: DigiPen, Institute for Systems Biology, and Bio-ITEST

Early in 2011, Raymond Yan, Chief Operating Officer of DigiPen Institute of Technology and Bio-ITEST Advisory Board Member suggested a new program that went beyond the scope of our original grant and reached students directly. This idea grew into a partnership among DigiPen, the Baliga Lab at the Institute for Systems Biology, and the Lake Washington School District to present three-week summer workshop to introduce students to systems biology, bioinformatics and molecular biology. Claudia Ludwig, M.Ed., Education Program Coordinator for the Baliga Lab, and Dina Kovarik, M.S., Ph.D., Program Manager for Bioinformatics at NWABR developed the course framework for "Dynamic DNA: Exploring Biological Systems," which was approved by Washington's Office of Superintendent of Public Instruction for 0.5-credits of career and technical education (CTE) at the high school level. The course was taught by Bio-ITEST alumni Tamara Caraballo, M.Ed., of Glacier Peak High School and Mari Knutson Herbert, M.Ed., of Lynden High School. In addition to attending both the February 2010 and August 2010 Bio-ITEST teacher professional development workshops, Ms. Caraballo was a Bio-ITEST pilot and field test teacher for both the Introductory and Advanced Bio-ITEST curricula, and her students took part in the DNA barcoding research projects. Ms. Herbert joined the Bio-ITEST team for the February 2011 teacher professional development workshop, and has worked extensively with the Baliga Lab on their systems biology research.

Systems Biology Curriculum

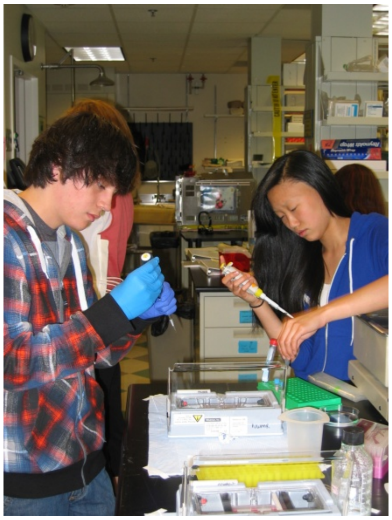
Students began this workshop at the DigiPen campus in Redmond, WA with an exploration of systems biology: a biology-based interdisciplinary field that focuses on complex interactions in biological systems. 21st century biotechnology allows for rational modification of systems due to predictive biology processes. In this workshop, students gradually internalized the thinking and content needed to address pertinent systems and biotechnology problems. Students began by using a familiar scenario, cell phone networks, to understand basic system dynamics along with the tools needed for analysis and visualization. They applied their new understanding as they engaged in a complex case study involving unknown changes to ecological and cellular systems. While investigating, students used systems thinking along with basic microbiology techniques, technology, and statistical analysis to come to a big picture view of what caused these changes, what reverberating effects were likely, how changes can be predicted in the future, and how they can develop reliable technology needed to support their conclusions and guide future hypotheses. The future of biotechnology depends on developing a STEM workforce that understands systems thinking and interdisciplinary problem solving, and is equipped to responsibly tackle societal and individual issues (such as sustainability, health of self, community, and home/planet). These modules, along with the curriculum below, strategically helped to build the skills necessary to prepare tomorrow's STEM workforce.

Bioinformatics Curriculum

Building on student understanding of how genes and proteins function as components of networks within the cell and within the body, students next explored the field of bioinformatics: the development and use of computational tools to expand the use biological data, including methods to acquire, store, organize, visualize and analyze such data**.** New developments in bioinformatics also raise bioethical issues. In order for young people to truly understand what biology today is all about, they need to understand the integral role that information technology plays in research. Using the breast cancer susceptibility gene *brca1* as a model, students explored the ethical issues surrounding genetic testing and were introduced to a collection of bioinformatics tools. As biomedical researchers discover an increasing number of genes associated with susceptibility to disease, the era of "personalized medicine" has become a reality. Students will need to understand disease risks and genetic penetrance, how genetic information is acquired, stored, and used, who has access to their information, and how genetic testing can influence personal and health decisions for themselves and their families. Empowering students to understand the science behind genetic testing also reinforces lessons in evolution, Central Dogma, and the relationship between protein structure and function.

Molecular Biology and DNA Barcoding

Students further developed their skills as they explored molecular biology: the branch of biology that deals with the molecular basis of life, including the study of DNA and proteins. In this module, students explored how bioinformatics and molecular biology are used to perform genetic research. During the past several years, scientists from around the world have been endeavoring to standardize species identification through a process called DNA barcoding (described in the "Student Research Projects" section of this report). This involves sequencing small regions of the genome to identify and catalog all life on earth. Students began the unit in the Student Training Lab at the Fred Hutchinson Cancer Research Center (FHCRC) in Seattle, learning how to purify DNA from different salmon samples purchased at different grocery stores in the area. They then amplified the *COI* gene, analyzed their results using agarose gel electrophoresis, and sequenced their DNA product. Between experiments, students had lunch with FHCRC scientists, learning about their work and the various career pathways each took to get where they are today.



Students purify DNA from salmon for barcoding.

Careers

Throughout each of the modules, students were presented with a number of career options in which the tools of systems biology, bioinformatics, and biotechnology are used. A career module near the end of the workshop helped students develop important vocational skills, including writing a resume which links their classroom and laboratory skills to skills they can use in the workplace, as well as writing a cover letter to apply for a job or internship. Three Dynamic DNA students used their resume and cover letter writing skills to apply for internships with Bio-ITEST and ISB scientists. One of these interns is still working with the Bio-ITEST program more than six months later.

Game Design and Presentations of Student Work

Utilizing the gaming expertise of the DigiPen Institute of Technology, students attended lectures by DigiPen staff about basic game theory and design. This included how to make and test a prototype of the game, and revise the design following field testing. Connections were made between this process and the scientific method, in which data is generated and used to refine or refute a hypothesis. During the final week of the course, students were asked to pick a lesson that they really enjoyed and develop a game to teach that same lesson to other students. Most students worked in pairs, assisted by a DigiPen instructor and Dynamic DNA staff during the afternoon game planning sessions. One pair developed a YouTube-based quiz game with questions about DNA and genetic testing. Another pair developed a three-dimensional version of tick-tack-toe utilizing game cards with information about genetic mutations and disease, in which the corresponded deletions would “delete” the other player’s game piece from the board, or “insert” one of your own. The workshop concluded with a scientific conference, in which students presented what they had learned and the games that they had developed to their peers, significant adults, ISB and NWABR scientists and staff, and DigiPen students and instructors.

At the Dynamic DNA end-of-course conference, students present their science board game (top) and the prototype of 3-D Tic-Tac-Toe (bottom).

Professional Development for Teachers

Over the past year, Bio-ITEST has provided professional development for 55 teachers at two professional development workshops and a reunion for Bio-ITEST alumni. In total, we have reached over 210 teachers through these workshops, presentations at education conferences and webinars in Y3. Through the Bio-ITEST teachers who have participated directly in our professional development workshops, we have also reached over 700 students.

***An Introduction to Bioinformatics:* February 4-5, 2011**

18 teachers from across Washington State joined the Bio-ITEST project team for our 1.5-day professional development workshop, which provides teachers with an overview of the Bio-ITEST Introductory curriculum, *Using Bioinformatics: Genetic Testing.* The evening workshop session was held at Novo Nordisk, a global healthcare provider with a research facility in Seattle. Specializing in inflammation-related diseases, Novo researchers utilize cutting-edge bioinformatics tools to identify new drug targets for diseases such as diabetes, lupus, and rheumatoid arthritis. After an introduction to Novo Nordisk and how they use bioinformatics, teachers toured the facility with Novo staff and viewed research posters highlighting some of the many research projects currently underway. During a panel discussion and dinner with these researchers, teachers are able to ask questions and learn more about how the diverse career paths that many researchers took to achieve their current positions. During the all-day Saturday session, teachers experienced the Introductory curriculum firsthand, working through lessons in the computer labs and classrooms at Shoreline Community College.

"Thanks to Novo scientists for hosting! It's great to meet people who are passionate about their jobs!"

"The tour of the lab was especially helpful in getting us excited about why this is important to learn."

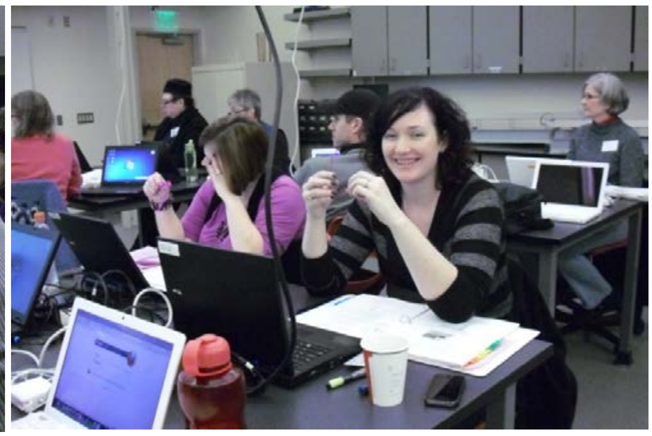
Prior to the workshop, teachers were provided with a workshop syllabus and background readings, introducing bioinformatics, genetic testing, and the role of the *BRCA1* gene in breast and ovarian cancer. Homework questions were designed to help teachers understand the role of bioinformatics in the increasingly data-driven science of today, while exploring some of the ethical considerations in the acquisition and use of genetic data. Most teachers taught at the high school level, in both public and private schools, including schools offering technical skills training.

"Wow! I really appreciate the extensive and well thought out lesson design. Everyone was very helpful."

"I really appreciate getting time to work with NCBI, NWABR, and Cn3d programs. The hands-on was necessary to learn. Curriculum available online is great and easy to access."

"Stellar curriculum. I am excited to use this in my classroom. This is a great integration of research ethics, cutting-edge science and math, and career opportunities. Thank you."

The professional development model utilized by Bio-ITEST has many benefits. Teachers "became the students," experiencing each lesson "firsthand," as their students would. This provided opportunities to ask questions and gain insights about how each lesson could be implemented in their classrooms. By including scientists throughout the evening session – as tour guides, members of the panel discussion, and dinner guests – teachers were able to interact with and question scientists about their work and experiences using bioinformatics every day. Teachers indicated that the chance to "network" with professional scientists, as well as with other science teachers, was of great benefit to them.



2011 Bio-ITEST Introductory Workshop Teachers work together to learn how to use the molecular viewing software Cn3D (left) after modeling protein/substrate interactions ("Pencil Transferase") (right).

Bio-ITEST Teacher Reunion: **May 24, 2011**

Teacher alumni from all Bio-ITEST workshops were invited to our first annual Bio-ITEST Teacher Reunion held at the Institute for Systems Biology in Seattle, WA. 13 teachers from Washington State joined the Bio-ITEST team for dinner, a discussion of their experiences using the Bio-ITEST lessons, and small and large group discussions about both teacher and student impacts of Bio-ITEST participation, and "big picture" issues relating to incorporating career awareness into the science classroom. Teachers were also asked to complete a pre-reunion questionnaire, which asked about the most effective aspects of the professional development workshop they attended, areas for suggested program improvement, and other comments they wished to share.

"To be honest, I didn't even know what bioinformatics was when I signed up for the class, yet was able to implement the curriculum and teach my students the material the first time I tried it. That was only possible because of the training I received in the workshop."

Adam Waltzer shows off his new systems biology education kit.

After dinner and discussions, teachers received training in using an inquiry-based systems biology module developed by our partners in the Baliga Lab at ISB. Systems biology, with its emphasis on interdisciplinary research and complex interactions in biological systems, is increasingly important to understanding and applying the results of genetic research, as well as genetic testing. Understanding genetic networks and complex interactions in biological systems can be challenging concepts for students. The "Environmental Impact on Gene Networks" module teaches students how to complete the steps scientists take when using systems biology to investigate how organisms induce phenotypic changes in response to the environment. Student teams apply their background knowledge of genetics and networks to experiment with a model organism. They then exchange and interpret information in order to build a possible network, and in the laboratory, test this network by altering environmental conditions. This leads to further experimentation to verify and draw conclusions about network interactions using experimental data and a computer simulation. Students act as scientists while planning, implementing, and evaluating an investigation in the context of a real regulatory network. Each teacher attending the Reunion received an "Environmental Impact on Gene Networks" module, complete with bacterial cultures and other supplies to implement the lessons in their classrooms.

Using Bioinformatics: Genetic Research: **August 1-5 and 8-12, 2011**

Using Bioinformatics: Genetic Research is a two-week professional development experience for teachers to learn about both the Introductory and Advanced Strand Bio-ITEST lessons. In August 2011, 24 high school science teachers traveled to Seattle from the around the Puget Sound region and from around the country (Washington, Oregon, California, Texas, Maryland and North Carolina) to receive training in the use of bioinformatics tools to analyze DNA sequences, perform multiple sequence alignments and explore protein structure.

In advance of the workshop, held at Shoreline Community College, teachers received background readings and homework assignments to introduce them to bioinformatics, genetic testing, and DNA barcoding. During Week 1 of the workshop, teachers began by setting "group norms" and devising strategies to let Bio-ITEST staff know when the complex material was getting overwhelming. Teachers agreed to respect others' opinions, share speaking time, and refrain from being judgmental. Everyone was encouraged to ask questions and provide feedback, including the use of "Stars and Wishes" sheets passed out daily to let staff know what was working ("Stars") and what was not ("Wishes"). Teachers then received training in basic computer skills before learning how to use the Introductory lesson materials with students. The opportunity to experience each of the lessons themselves, as their students would, is a cornerstone of NWABR's professional development model. Lead Teacher Adam Waltzer, who was a participant of the 2010 Bio-ITEST Professional Development Workshop and is an experienced biology teacher, assisted the Bio-ITEST team throughout the workshop, presenting materials and sharing his experiences field testing the lessons with his students. Including Lead Teachers in workshops is another important aspect of our professional development, as their experiences in the classroom using our curricular materials lend unique insight and perspective to our programs. Adam's curriculum comments informed the final rounds of lesson revisions, and his "social mixer" activity was included in the Advanced curriculum career lesson (see lesson summaries in the Curriculum section).

After learning about the use of numerous bioinformatics resources, including the NCBI and the search engine *Entrez*, as well as instruction on viewing macromolecules using Cn3D, teachers performed lab experiments in Shoreline's Biotechnology Laboratory. In addition to experiencing the high quality lab facilities at Shoreline Community College, teachers also had the opportunity to learn about Shoreline's Biotechnology Lab Specialist program, which prepares students for careers in biotechnology research and development through "hands-on" learning. As the focus of the Advanced curriculum is DNA barcoding, a primary goal of the workshop was for teachers to experience the entire barcoding process: obtaining a sample from an organism, purifying the DNA and sequencing the barcode region, analyzing the DNA data, and comparing that data to sequences contained in data repositories like the NCBI and the Barcode of Life Database (BOLD). Beginning with basic laboratory safety and

2011 Bio-ITEST Advanced Workshop Teachers explore the protein structures with Cn3D (left) and discuss the ethical issues surrounding genetic testing (right).

micropipetting, teachers spent a few hours each day working in the Biotech lab. They isolated DNA from samples provided through our partnerships with the Seattle Aquarium and the National Oceanographic and Atmospheric Administration (NOAA), including biopsy samples from sixgill and sevengill sharks, octopus, squid, and various fish species. Using their DNA samples, teachers then performed polymerase chain reaction (PCR), agarose gel electrophoresis, PCR sample purification, and submitted their DNA samples for sequencing. In addition to gaining experience in the lab and better understanding how biological data is generated, these teachers contributed to the body of scientific knowledge about species diversity, with implications for conservation. This sequence data will also be made available on the Bio-ITEST website for use in high schools by students who lack access to a wet lab.

"Bioinformatics is huge and will be driving the advancement of biological studies."

[The most significant take-away from this workshop is the …] "Connections to both NWABR and other teachers using this material. Having people to email or talk to makes the difference in implementing new materials."

Teachers worked in teams to purify DNA and amplify and sequence the barcode region of the cytochrome c oxidase subunit 1 (COI) gene from biopsy samples provided by the Seattle Aquarium and NOAA.

Many teachers found the lab experiments very engaging as they worked together in pairs or small groups. Those with more lab experience were encouraged to partner with those who had little to no experience in a molecular biology lab, and by the end of the second day of lab experiments, a great sense of teamwork and camaraderie had developed. Bio-ITEST program staff members, many of whom were bench scientists, were present throughout the experiments to offer instruction and assistance. Teachers used the DNA sequence data they generated in Week 1 for their exploration of the Advanced strand lessons during Week 2. By the end of the activities, teachers were able to better understand the flow of biological data generation, from the lab bench to the computer. In addition, teachers provided many helpful suggestions to improve the usability of the lab protocols and enhance student understanding of each step in the experimental process of DNA barcoding.

The most effective aspects of the workshop were all of the computer programs. I never realized how much information was out there with regard to DNA analysis. I really enjoyed all of the case studies and activities.

The most valuable skills I acquired were gaining understanding of, and access to, the online bioinformatics tools. I am also very happy to have had the opportunity to conduct another PCR wet lab. Finally, the ability to have DNA sequencing performed on their PCR products is tremendously exciting.

During Week 2 of the workshop, teachers received additional background on the *COI* gene, which is the focus of the Advanced Strand student research project. They also received training in the use of software and online programs for annotating DNA sequences, performing multiple sequence alignments, and using bioinformatics tools to study evolutionary relationships.

"The most significant factor is a fully contained & guided curriculum unit with associated resources. I will be able to teach these units and easily integrate them into an adv. class. It is also significant that the career focus is included, as this is a goal of the CTE program."

"I'm excited too about the 3D protein model. I did not know the outer subunits came from chromosomal DNA and the inner from mitochondrial. I wonder how that relates to the endosymbiout theory. This protein will make a great foundation for teaching biology."

"The availability of resources and information on the Internet for public/classroom use is very exciting!"

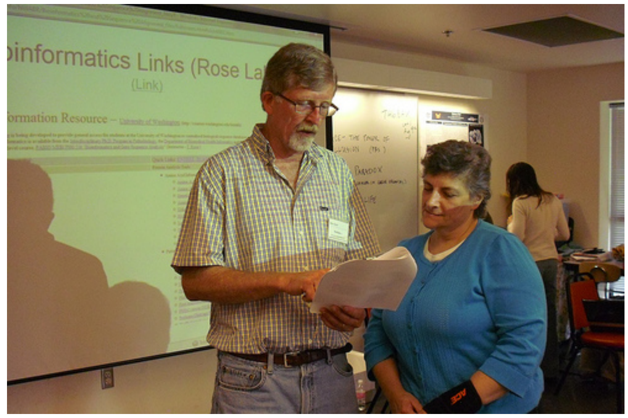
To learn more about bioinformatics and how it is utilized in cutting-edge science, teachers spent a day touring two local research facilities: the Bumgarner Lab, which is part of the University of Washington, Department of Microbiology; and the Institute for Systems Biology (ISB). During the tour of the Bumgarner lab, teachers received a lecture from Dr. Roger Bumgarner about next generation DNA sequencing, which makes it possible to sequence an entire microbial genome in only a few days – faster than a similar technique teachers learned about only a year before! They also saw the laboratory and machinery which makes this "high throughput" DNA analysis possible.

Teachers and a Career and Technical Education (CTE) Director received a tour of his lab from Dr. Roger Bumgarner (left) and visited with scientists at the Institute for Systems Biology (right).

Systems biology is a term used to describe a number of trends in bioscience research, and a movement which draws on those trends. It is often described as a biology-based inter-disciplinary field of study that focuses on *interactions* within biological systems, looking at the entire system as a whole, instead of trying to understand that systems based only individual pieces or parts. At the Institute for Systems Biology, teachers toured multiple labs and common core facilities in small groups, led by ISB scientists from many different backgrounds. Systems biology draws on a number of different disciplines, from molecular biology and systematic, to genomics, proteomics, metabolomics, and microbiology, many of which are made possible by bioinformatics and computational biology. Jen Eklund, Education Liaison for the Center for Inquiry Science at the ISB facilitated our visit, and shared with our group the launch of their new website and video to teach secondary students about personalized medicine and the impact of genomics on their lives. Dr. Nitin Baliga, ISB faculty Bio-ITEST Advisory Board member, talked to teachers about the value of integrating systems biology into high school science classes, using his lab's education modules for guided inquiry. The partnership between Bio-ITEST and the Baliga Lab's educational program has continued to developed during Y3 of our project, with Bio-ITEST alumni receiving training in using the Baliga lab's modules during the May Reunion and the collaboration between our two groups to hold our first student summer course, "Dynamic DNA," both described elsewhere in this report.

"Before I knew some things existed at NCBI but wasn't sure how to use it. Now I am excited that I know where things are and how to use them. I know I don't know everything but I am adventurous and I will keep on learning what I can thru web resources and other people. I will look for opportunities where I can extend and integrate those tools. I have a bunch of ideas already that I want to try. So if I don't use the curriculum exactly the way it is presented I will use a portion or a variation. I am excited to also share info with those kids who are interested in doing more in a kind of extracurricular format like a service club and/or science research projects for the Intel Science and Engineering Fair."

Guest speakers featured prominently in this year's workshop, including scientists from academia, industry and government. Tim Rose, Ph.D., of the University of Washington, Department of Medicine, and Seattle Children's Research Institute introduced teachers to bioinformatics and multiple sequence alignments during Week 1 of the workshop. As a Bio-ITEST Advisory Board member and instructor for a graduate-level bioinformatics course at UW, Dr. Rose is intimately familiar with the goals of our project and the benefits and challenges of integrating bioinformatics concepts in a biology curriculum. Teachers resonated with Dr. Rose's approach to the subject, and discussions about utilizing his work on the *ACBP* gene to teach concepts in evolution and phylogenetics continued well past his talk. Todd Smith, Ph.D., formerly CEO of Geospiza and now a Senior Project Leader at Perkin Elmer, also spoke to teachers during Week 1 of the workshop. Also a Bio-ITEST Advisory Board member, Dr. Smith offered insights into research opportunities in industry, where an increasing number of new jobs are being created, and described the advances in communications and information technology that have made international collaborations in science the norm, not the exception. Students today are truly digital natives, and their fluency with informational technology will serve them if they pursue a career in STEM.   Susan Hoyne, Ph.D., Dean of the Math and Science Division at Shoreline Community College spoke about biotechnology careers for students, and the educational opportunities available at Shoreline and other community colleges around the country. Sandra Porter, Ph.D., Bio-ITEST Co-PI and President of Digital World Biology shared the story of her career path with our Bio-ITEST teachers, including her experiences in both academia and industry, and the importance of community colleges and related programs to increase access to future STEM careers for students. Dr. Porter was a microbiologist and bench scientist before becoming Director of Education at the Seattle-based bioinformatics company Geospiza, a teacher at Seattle Central Community College and Austin Community College, President of Digital World Biology, and developing the widely-read blog, *Discovering Biology in a Digital World.* Dr. Porter is also the Co-PI on Bio-Link, a National Advanced Technology Education (ATE) Center of Excellence grant focused on Biotechnology and Life Sciences, funded in part by the National Science Foundation (DUE 0903317). Advisory Board member and Chief Data Officer at Seattle Children's Research Institute, Eugene Kolker, Ph.D., spoke to teachers during Week 2 about his work in proteomics and the applications made possible by advancements in information technology and collaborative platforms such as his S.P.I.R.E. program. The final guest speaker at the workshop, Piper Schwenke, Forensic Molecular Geneticist at the National Oceanographic and Atmospheric Administration's (NOAA) Fisheries Department, described through case studies how bioinformatics and molecular techniques have impacted the field of forensics, leading to convictions of illegal poachers and peddlers of protected fish species. The teachers were so impressed by Ms. Schwenke and her work, and number of them invited her to



Dr. Tim Rose, Guest Speaker and Advisory Board Member, talks with Bio-ITEST Georgi Brunning about using bioinformatics in the classroom.

speak to their classes, and she took part in a webinar about biosciences careers with the Bio-ITEST team and ITEST programs Learning Resource Center.

"The most significant take-away from this workshop is the importance of exposing students to STEM careers, particularly those using bioinformatics. This is an area in which I have much room for growth and really value the resources provided."

"The science careers are another plus. I didn't know how to pass on science career info before but have a platform to teach it now through this curriculum. I fell more confident in being able to advocate for students to pursue a science career."

To further explore how teachers fostering student career awareness, the Bio-ITEST project team conducted a guided group discussion around the following questions: (1) What do you see as the role(s) of science teachers in helping students become aware of, and prepared for, STEM-related careers? (2) How do you stay abreast of emerging STEM-related career opportunities, pathways, and requirements? (3) What support would be useful to you as a teacher to maintain or increase your own career awareness? And (4) Besides addressing these technology and time constraints, what policy changes, support, or resources do science teachers need to engage in career-related activities with their students? In describing their roles in helping students prepare for STEM careers, teachers described activities such as connecting skills and content to diverse and emerging careers; being a "conduit" to new careers and ; teaching the process of science, and not just science content, so that students can better understand how science is done; being a link between the outside world and students, and sometimes even be a link between students and career counselors, and providing exposure to careers through experiences such as field trips and guest speakers. Teachers also described the barriers to these activities, explored more fully in our "Emerging Role of Science Teachers" study described earlier. These barriers include challenges in obtaining funding for substitute teachers and field trips; a lack of real-world science experience for teachers; the fact that science careers are covered only briefly, or not all, on standardized tests; and the absence of science career content and guidance during their pre-service teacher education. When asked how teachers stay abreast of science careers, some said "not at all," professional development workshops like those provided by NWABR and the Science Education Partnership (SEP), networking and word of mouth, and emails from groups like SEP and NWABR. These groups have demonstrated their creditability and relevance, and some teachers make a point of reading emails from these groups, "even when their email inbox is quite full." In response to questions about the type of support that they need to integrate more information about careers into their classrooms, teachers replied with requests for more foreseeable resources like money and release time, but also opportunities to allow teachers to go into the field to do science, more science speakers for their classes, Career Days, career-infused curricular materials, and other "Career Bites" that are easy to plug in to daily lesson plans "on the fly." **Many of these requests can be fulfilled with little resource investment on the part of school districts or local governments, and could have profound implications for our future STEM workforce.**

"I am excited to bring some of the tools to my kids. Specific activities: using CN3D to look at protein structures; Jeanne's pipe cleaner activity; the career slides as a "career of the week;" using BLAST AND BOLD to compare sequences and to create phytogenetic trees; several ethical issues brought up (specifically the scenario w/ BRCAI & the funding of rare diseases)."

To gauge the impact of the 2011 Bio-ITEST Advanced Professional Development Workshop, *Using Bioinformatics: Genetic Research*, the evaluation team administered surveys at the beginning and end of the workshop to measure teacher change as a result of their participation. The surveys, which were developed for the prior year's research study, consisted of seven pre/post items measuring teacher Engagement, Awareness, and Self-efficacy related to bioinformatics databases, teaching resources, and career information. The post-workshop survey also included five retrospective items, asking teachers to compare their levels of knowledge and skills as a result of their participation by looking back at where they were "before the workshop" vs. "now." Finally, the surveys collected evaluative information on teachers' plans to teach the curriculum, as well as demographic and background characteristics. 23 teachers in the workshop took the pre-workshop survey; 21 teachers took the post-workshop survey.

Eighty-six percent of workshop participants were white, 81% were female, and none were Hispanic/Latino. Teachers represented 19 different schools. Most had masters or doctorate degrees (81%) and teaching certifications in biology (71%) and another science certification (67%). Four teachers (19%) had career or technical education certifications. This group of teachers was quite experienced overall, with an average of over ten years of high school teaching experience and almost nine years teaching biology. One-third of teachers reported prior professional development in bioinformatics, two-thirds in integrating ethics into science curricula.

Teachers made statistically significant gains on all but one of the seven items from the beginning to the end of the workshop (Figure 6). Awareness and Self-efficacy items showed the greatest increases, followed by Engagement measures. The results from the 2011 workshop closely mirrored 2010 workshop ratings and on almost all items, teacher pre- and post-workshop ratings did not differ statistically from one year to the next.

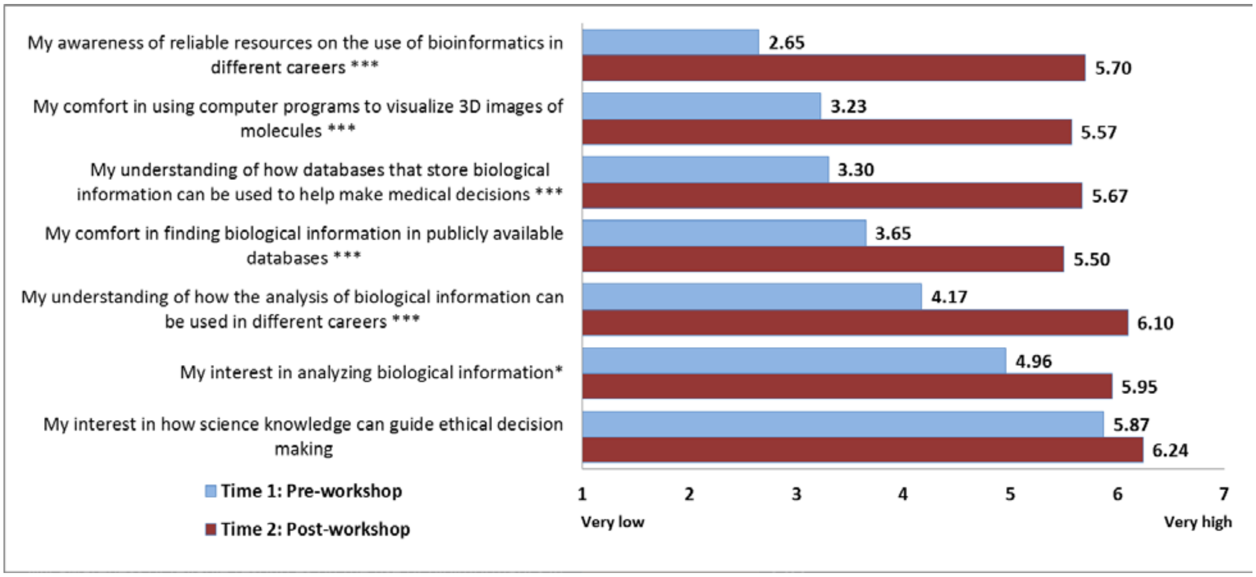


Figure 6: Matched Pre- and Post-survey Findings, 2011 Bio-ITEST Advanced Professional Development Workshop, Using Bioinformatics: Genetic Research (N = 21). Items are arranged in the order of pre-workshop means. * p < 0.05 ** p <0 .01 *** p <0 .001

Teachers were also asked to rate how much they had changed, in retrospect, as a result of the Bio-ITEST workshop, "Before" the Bio-ITEST workshop versus "Now," to obtain teachers' assessments of changes that they themselves attributed to their workshop participation. **Teachers attributed dramatic improvements in their abilities and awareness to having participated in the workshop (Figure 7).** Four out of five items increased by three points or more, and changes from before the workshop to after the workshop were statistically significant on all items. **The greatest gains were seen in their perceived abilities in using bioinformatics resources to support classroom instruction, using bioinformatics tools, and accessing information in biological databases.**

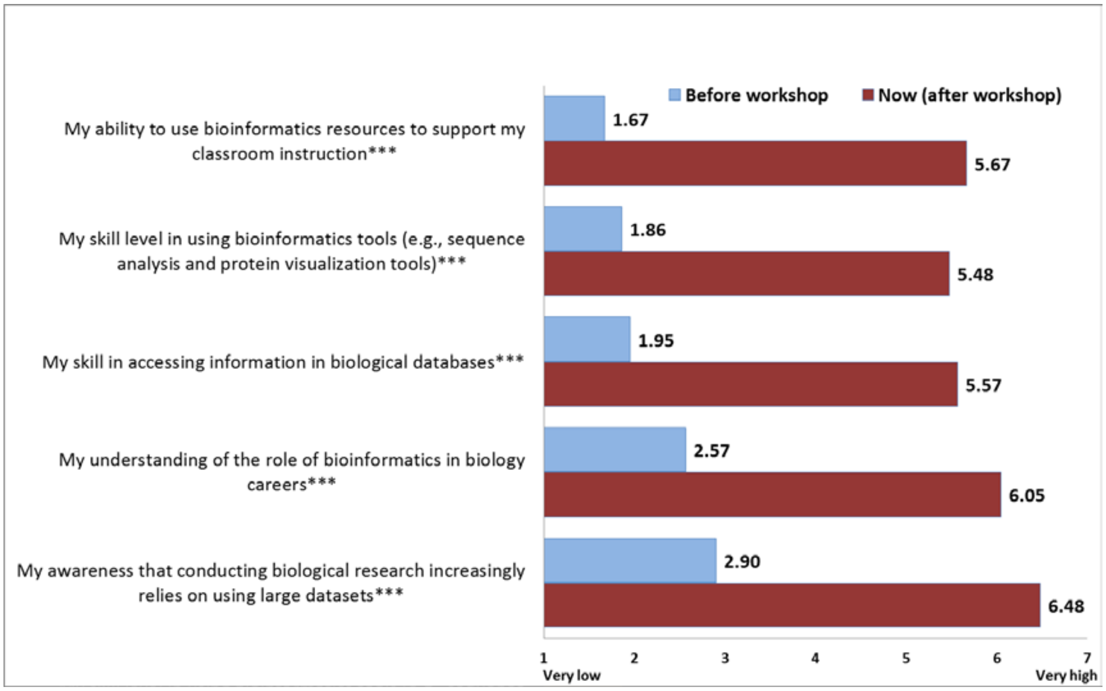


Figure 7: Post-Workshop Survey Retrospective Ratings of Workshop Impact, 2011 Bio-ITEST Advanced Professional Development Workshop, Using Bioinformatics: Genetic Research (N = 21). Items are arranged in the order of pre-workshop means. *** p <0 .001.

Teachers were also asked about the ways they currently integrate information about science careers in the classroom in the pre-workshop survey. They were allowed to check more than one practice and offer others not listed (Table 4). The most common practice, reported by 33% of teachers, was having guest speakers, followed by field trips to work sites (24%), and student research on career paths (19%). The vast majority of teachers, 76%, reported using one or two of these practices, while one teacher reported no integration of science career information, and four teachers reported using three or four practices. Six teachers reported that they also used personal anecdotes to provide science career information to students.

Table 4. Teacher Integration of Science Career Information in the Classroom

Practices to integrate science career information		N	%
Guest speakers in classroom		7	33 %
Field trip to worksite		5	24 %
Student research on career paths		4	19 %
Student research projects on science careers		3	14 %
Student interviews with scientists		1	5 %
Participation in BioExpo		1	5 %
Other not listed above		14	67 %
Total number of practices reported by each teacher: N (%)			
0 practices	1 (5%)	**3 practices**	3 (14%)
1 practice	10 (48 %)	**4 practices**	1 (5)
2 practices	6 (29%)		

"This was an amazing and engaging workshop! I feel more confident in teaching many of these concepts and can't wait to share them with my colleagues! I also feel smarter (not that this was one of the goals)."

"This has been 1 of my favorite workshops I've ever attended. The information and resources provided were awesome and I feel my students will benefit from this. I think all teachers should be exposed to this professional development."

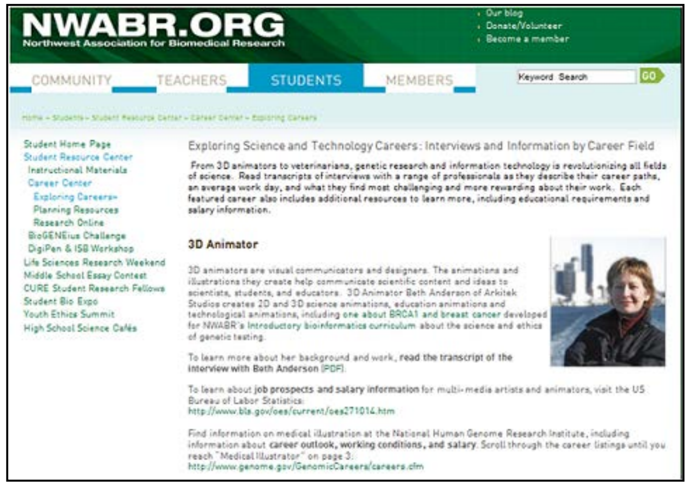
Over 24 scientist volunteers contributed over 80 hours of time for the Bio-ITEST teacher programs.

Other Professional Development and Invited Presentations

Because of the continued high demand for quality educational materials that address the increasingly data-driven nature of science and the bioinformatics tools needed to make sense of this data, as well as the ethical implications of the acquisition and use of this data, we have been able to collaborate with several other programs to reach additional groups of teachers and students. We presented Bio-ITEST-related materials at the following professional development conferences:

Date	Site	Topics
January 2011	American Medical Writers Association of the Pacific Northwest	Bioinformatics and the Bio-ITEST Curricula
March 2011	National Science Teachers Association National Conference, San Francisco, CA	Introduction to Bioinformatics
March 2011	Washington Science Teachers Association Conference, Poulsbo, WA	Introduction to Bioinformatics
September 2011	ITEST Learning Center Public Webinar	Biosciences Careers and Bio-ITEST Career Resources
October 2011	National Association of Biology Teachers National Conference, Anaheim, CA	Introduction to Bioinformatics
December 2011	National Science Teachers Association Regional Conference, Seattle, WA	Introduction to Bioinformatics
February 2012	National Girls Collaborative Project Webinar	Biology in the Age of Computing

Building an Active and Engaged Online Community



The Bio-ITEST program has developed a series of new online resources, while building on existing resources created in Y1 and Y2. The Bio-ITEST Moodle site has continued to grow into a useful vehicle for teachers and program staff to share resources and information. The new NWABR website has provided a forum for wide dissemination of the Bio-ITEST curricular materials, and the Student Career Center now contains electronic versions of all Bio-ITEST career materials and interviews, as well as an increasing collection of bioinformatics and computational biology-related career information that could not be integrated into the final versions of the Bio-ITEST lessons. The Education and Career Planning webpage of the Student Career Center contains helpful information and links for students writing resumes and cover letters, applying to college, or applying for a job. Integration of these resources within the larger NWABR educational materials will sustain and grow their development for years to come.

The Bio-ITEST Curricula:
Final Versions of the Introductory and Advanced Lessons

An important component of the Bio-ITEST project was development of two bioinformatics curriculum units in partnership with curriculum development teachers, research scientists, bioethicists, field test teachers, and Bio-ITEST program staff. The Introductory unit, *Using Bioinformatics: Genetic Testing,* utilizes bioinformatics tools to teach and reinforce basic concepts in molecular biology. The Advanced unit, *Using Bioinformatics: Genetic Research,* incorporates additional informatics resources and includes an authentic inquiry-based investigation specifically for advanced students.

Curriculum Development:

<u>Partnership with Educators</u>

Six experienced teachers from Washington and Oregon were recruited to help provide the broad outline of two bioinformatics-related curricula during a two-week curriculum development workshop held in summer 2009. The first week of the workshop involved immersion in bioinformatics and molecular biology. Teachers performed wet lab experiments, including DNA purification, polymerase chain reaction (PCR), agarose gel electrophoresis, and DNA sequencing to gain experience with the procedures involved in generating DNA sequence data. In addition, teachers visited laboratories in the Seattle area that conduct bioinformatics-related research, meeting with scientists and discussing their work. During the second week, teachers utilized the "Understanding by Design" framework (Wiggins and McTighe, 1998) and a variety of relevant readings to set curriculum goals and finalize the essential understandings and unit objectives that would be contained in the Introductory and Advanced bioinformatics curricula. Using this as a foundation, Bio-ITEST project staff and project partners further developed these ideas and finalized a draft of the Introductory curriculum in January 2010 and a draft of the Advanced curriculum in July 2010, both of which are mapped to the National Science Education Standards and the Next Generation Science Standards.

Expert Review

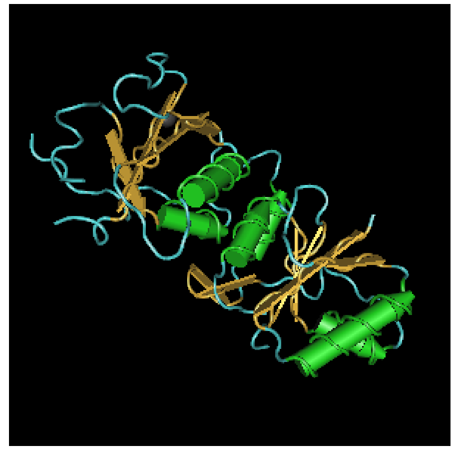
To ensure the accuracy and authenticity of Bio-ITEST curricular materials, as well as obtain important feedback about lesson composition and flow, NWABR recruited experts to review both curriculum units. Reviewers included Brian Fox, Ph.D., Senior Scientist of Computational Biology at Novo Nordisk, a Seattle biotechnology company; Mette Peters, Ph.D., Director at the Institute of Translational Health Sciences at the University of Washington; and Carol Farris, Ph.D., Postdoctoral Fellow in the Department of Biomedical and Health Informatics and the University of Washington. In addition, high school and college students were recruited to provide feedback on each of the lessons. Professional curriculum consultant, Kristen Clapper Bergsman, M.Ed., of Laughing Crow Curriculum, L.L.C., contributed her curriculum development experience, subject matter knowledge, and expertise in meeting the needs of high school educators. Both curriculum units were field tested extensively with more than 30 teachers in a variety of educational settings, including middle school and high school introductory biology and biotechnology courses. After each teacher implemented a curriculum unit, written feedback was provided to the Bio-ITEST team, and informed the following rounds of on-going and iterative curriculum revisions. Detailed written feedback was also obtained during lesson presentation at the professional development workshops in 2010 and 2011.

Publication: Excerpt of Curricular Lesson for Practitioner Audience

Our paper entitled "Modeling Protein Structure and Function: Pencil Transferase" has been accepted for publication by *The American Biology Teacher* and will appear in the October 2012 issue. Adapted from Lesson Five of the Introductory curriculum, this hands-on activity uses modeling with pipe cleaners (chenille stems) to help reinforce the connection between the ultimate spatial conformation of a specific protein ("pencil transferase") and its "job" – in this case, moving a pencil from one desk to another. The model demonstrates the relationship between protein structure and function, the importance of functional domains, and the potential impacts of mutations.

The Introductory Curriculum: *Using Bioinformatics: Genetic Testing*

The Introductory curriculum, *Using Bioinformatics: Genetic Testing,* introduces students to a collection of bioinformatics tools and explores the ethical issues surrounding genetic testing. Students investigate the genetic and molecular consequences of a mutation to the Breast Cancer susceptibility 1 (*BRCA1*) gene, using the bioinformatics tools BLAST (Basic Local Alignment Search Tool) to compare DNA and protein sequences, and Cn3D to visualize molecular structures. The curriculum begins with a student performance of the play "Meet the Gene Machine," developed by the Wellcome Trust charitable foundation in the United Kingdom, and used with permission. The play sets the stage for the rest of the curriculum, helping students explore some of the myths and realities of genetic testing today as they follow the story of a family considering genetic testing for *BRCA1* mutations. Students are also introduced to principles-based bioethics in order to support their thoughtful consideration of the many social and ethical implications of genetic testing. With a strong emphasis on encouraging student interest in STEM careers, each lesson features an individual who uses bioinformatics in his or her work, or whose work is made possible by bioinformatics (see lesson summaries below). In the culminating career lesson, Lesson Seven, students explore each featured career in greater depth, including transcripts of interviews with each career professional, and write a bioinformatics-related resume. All lessons and related resources are freely available to download from NWABR's Introductory curriculum webpage at: http://www.nwabr.org/curriculum/introductory-bioinformatics-genetic-testing.



A Region of the BRCA1 Protein. Adapted from Williams et al. 2001

"I think being able to learn about various careers and how the learning each day is relevant to a particular career has been very valuable for my students. I struggle to incorporate this piece into my teaching on a regular basis. To have the career tie-in treated with intentionality and structured in a way that encourages students to really pay attention, was fabulous. They also were able to see an application of technology in science, and for my students, I think that was greatly valuable as well."

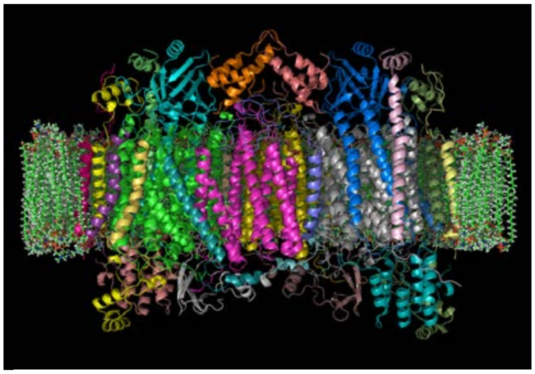
"What they liked was that it (BLAST) wasn't a "made for students program." They got the idea that they were able to use some of these tools that real researchers are using, that they can just look up stuff and find things. They really liked it, they asked, "Is this a thing that scientists use?" They liked that idea that they were learning something real, not a made-up situation."

Introductory Curriculum Lesson Overview: *Using Bioinformatics: Genetic Testing*

Lesson	Title	Synopsis
I	**Bioinformatics and Genetic Testing**	A short topical play introduces students to the fields of bioinformatics, genetic testing, direct-to-consumer genetic testing, and ethical considerations. Students discuss some of the broad implications and ethical questions raised from gaining information through genetic testing. Students then consider a number of genetic tests and their potential usefulness and value and, as a class, explore the website of 23andMe, a company that offers direct-to-consumer genetic tests. The lesson wraps up as it began—by engaging students in a story. Through a short video, students are introduced to a family impacted by breast cancer. In Lesson One, students also learn how ***bioengineers*** might use bioinformatics tools in their career.

2	**Navigating the NCBI**	Students navigate parts of the National Center for Biotechnology (NCBI) website and work independently to explore databases, focusing on the *BRCA1* gene and the bioinformatics tool Map Viewer. Through an analogy that compares two collections of databases (iTunes® and the NCBI), students connect with their own prior knowledge to better understand database structure and function. In Lesson Two, students learn how ***veterinarians*** might use bioinformatics tools in their career.
3	**Exploring Genetic Testing: A Case Study**	In this lesson, students engage in a case study about a family with a history of breast cancer. Students consider ethical issues surrounding genetic testing as they decide whether or not family members should get tested for *BRCA1* or *BRCA2* mutations. Students then evaluate the case through the principles-based bioethics concepts of: Respect for Persons, Maximize Benefits/Minimize Harms, and Justice. Students apply the principles to help them reason through their decision as they participate in a Structured Academic Controversy. In Lesson Three, students learn how ***genetic counselors*** might use bioinformatics tools in their career.
4	**Understanding Genetic Tests to Detect *BRCA1* Mutations**	Students begin this lesson by working through a pedigree chart and Punnett squares for the Lawler family, attempting to track the *BRCA1* mutation across generations. Based on the decisions as to who should be tested for the *BRCA1* mutation, students then use the bioinformatics tool known as BLAST (Basic Local Alignment Search Tool) to compare individual DNA and protein sequences to reference sequences that are known to be free of *BRCA1* mutations associated with cancer. At the end of the lesson, students compile class information from the Lawler family in order to revise their pedigree charts and Punnett squares. In Lesson Four, students learn how ***laboratory technicians*** might use bioinformatics tools in their career.
5	**Learning to Use Cn3D: A Bioinformatics Tool**	Up to this point, students have seen the BRCA1 protein represented in a linear, sequential form. In this lesson, students are introduced to the high importance of a protein's three-dimensional structure. Students first engage in a short activity in which they use a pipe cleaner to perform a simple function, as an analogy for the relationship between a protein's structure and function. Students then learn to navigate between linear protein sequences and three-dimensional structures by using the bioinformatics tool Cn3D. Students begin by viewing and manipulating DNA—a familiar molecule to students—using Cn3D. When students are familiar with the program, students visualize parts of the BRCA1 protein to show how a specific mutation in the *BRCA1* gene ultimately changes or destroys the protein's function. In Lesson Five, students learn how ***3D animators*** might use bioinformatics tools in their career.
6	**Evaluating Genetic Tests: A Socratic Seminar Discussion**	In this lesson, students apply the ethical skills and scientific knowledge they have acquired over the previous lessons to determine (1) whether *BRCA1* testing meets the standards of a useful genetic test, or (2) whether direct-to-consumer genetic testing should include genetic counseling of clients. Students or teachers may choose from one of two readings, after which students participate in a Socratic Seminar in order to deepen their understanding about genetic testing. Through the seminar discussion of the first reading, students become familiar with a framework for considering genetic tests in terms of their clinical validity and the availability of effective treatment. Through the

		seminar discussion of the second reading, students become familiar with issues and preliminary data regarding the effects of direct-to-consumer genome-wide screening. After the seminar, students are supported in coming to an individual position about genetic testing through the integration of scientific facts, stakeholder viewpoints, and ethical considerations. In Lesson Six, students learn how ***bioethicists*** might use bioinformatics tools in their career.
7	**An Introduction to Bioinformatics Careers**	In this lesson, students explore more deeply the information they have learned throughout the unit about people in various careers that use bioinformatics. Students choose one career they would like to learn more about. They further explore that career by reading a series of in-depth questions asked of the person highlighted in that career, as well as provided internet resources. Students then respond to a job posting for a summer internship in their chosen field, developing a resume for that position. Optional activities include peer-editing of resumes and socializing in a professional environment.
8	**Genetic Testing Unit Assessment: *ALAD* and *SOD1***	As an assessment of the unit, students revisit some of the bioinformatics tools they have used in prior lessons in order to locate a mutation in a protein associated with a genetic condition. Students also evaluate current genetic tests for the condition using the criteria of clinical validity and treatment options. Two conditions and their tests are presented: porphyria and amyotrophic lateral sclerosis (ALS).



The Cytochrome c Oxidase complex.
Adapted from Tsukihara et al, 1996.

The Advanced Curriculum: *Using Bioinformatics: Genetic Research* and DNA Barcoding

The Advanced curriculum, *Using Bioinformatics: Genetic Research,* explores DNA barcoding of animals with the cytochrome c oxidase subunit 1 (*COI*) gene, building on the lessons of the Introductory curriculum and incorporating additional informatics resources to teach concepts related to species diversity and evolution. Students use BLAST both to identify an unknown DNA sequence and to perform multiple sequence alignments (see lesson summaries below), as well as build phylogenetic trees and learn to use the bioinformatics tool ORFinder to identify open reading frames in a DNA sequence. As in the Introductory curriculum, each Advanced lesson features a professional who uses bioinformatics in their work, or whose work is made possible by bioinformatics. In the culminating career lesson, Lesson Eight, students read interview transcripts, perform career-related internet research, and build on the career skills developed in Introductory Lesson Seven by updating their resume, learning to write cover letters, and engaging in an optional mock job interview. Lesson Nine is an optional extension lesson in which students learn how to analyze DNA sequence data provided by the Bio-ITEST program or generated in their classrooms (Wet Lab). All lessons and related resources are freely available to download from NWABR's the Advanced curriculum webpage at: http://www.nwabr.org/curriculum/advanced-bioinformatics-genetic-research.

"They gained significant confidence in their ability to read, understand, and analyze data. It was fabulous!"

"The students were amazed what THEY could do and the information that was available to them."

"The ability to use various tools and data bases increased the students' skills and confidence in applying biology topics."

Advanced Curriculum Lesson Overview: *Using Bioinformatics: Genetic Research*

Lesson	Title	Synopsis
I	**The Process of Genetic Research**	In this lesson, students are introduced to the process of genetic research. The lesson begins with a Think-Pair-Share activity designed to introduce students to the types of research questions people in different career fields might answer using bioinformatics tools. After a short background explanation provided by the teacher about how genetic research is done, students make their own hypotheses or predictions about the relatedness of canine species, and align paper DNA sequences to evaluate their hypotheses. The lesson concludes with a group activity introducing students to pairwise comparisons of DNA sequences, which will be explored more fully in later lessons. In Lesson One, students also learn how ***DNA Sequencing Core Managers*** might use bioinformatics tools in their career.
2	**DNA Barcoding and the Barcode of Life Database (BOLD)**	In this lesson, students will receive an "unknown" DNA sequence and use the bioinformatics tool Basic Local Alignment Search Tool (BLAST) to identify the species from which the sequence came. Students then visit the Barcode of Life Database (BOLD) to obtain taxonomic information about their species and form taxonomic groups for scientific collaboration. The lesson ends with students generating a hypothesis based on the species within each group. In Lesson Two, students learn how ***postdoctoral scientists in DNA and History*** might use bioinformatics tools in their career.
3	**Using Bioinformatics to Study Evolutionary Relationships**	Students learn how to use bioinformatics tools to analyze DNA sequence data and make conclusions about evolutionary relationships. Students collaborate with their group members by pooling their DNA sequences from Lesson Two: DNA Barcoding and the Barcode of Life Database (BOLD) to perform and analyze multiple sequence alignments using the computer programs ClustalW2 and JalView. After comparing relatedness among and between the species within their group, students use their sequence alignment to generate a phylogenetic tree, which is a graphical representation of inferred evolutionary relationships. This tree is used to draw conclusions about their research question and hypothesis. In Lesson Three, students learn how ***microbiologists*** might use bioinformatics tools in their career.
4	**Using Bioinformatics to Analyze Protein Sequences**	Students perform a paper exercise designed to reinforce the concepts of the complementary nature of DNA and how that complementarity leads to six potential protein reading frames in any given DNA sequence. They will also gain familiarity with the circular format codon table. Students then use the bioinformatics tool ORFinder to identify the reading frames in their DNA sequence from Lesson Two and Lesson Three, and to select the proper open

		reading frame to use in a multiple sequence alignment using their protein sequences. In Lesson Four, students learn how ***biological anthropologists*** might use bioinformatics tools in their career.
5	**Protein Structure and Function—A Molecular Murder Mystery**	Prior to this lesson, students learned how the cytochrome c oxidase gene is used in barcoding organisms. In this lesson, students learn more about the cytochrome c oxidase protein and its three dimensional structure. In particular, students learn how to identify the active site in cytochrome c oxidase. Once they can find this site, they look at aligned structures (one of which contains a poison) and then identify the poison. This lesson allows students to explore the use of the molecular visualization software Cn3D to learn more about cytochrome c oxidase, a ubiquitous and important protein. In Lesson Five, students learn how ***molecular diagnostics researchers*** might use bioinformatics tools in their career.
6	**Writing Research Reports (Assessment)**	n this lesson, students compile and synthesize what they have learned in the preceding lessons by writing a research report. The research report includes Introduction, Methods, Results, Discussion, and References sections. Emphasis is placed on relating previous lesson activities to the original research question and hypothesis. Extensions and lesson alternatives include instructions for creating a scientific poster and writing an abstract. In Lesson Six, students learn how ***science and technical writers*** might use bioinformatics tools in their career.
7	**Who Should Pay? Funding Research into Rare Genetic Diseases**	Students learn about Leigh's disease, a rare form of Subacute Necrotizing Encephalomyelopathy (SNEM) that can be caused by a deficiency in cytochrome c oxidase (complex IV). Deficiencies in the large, 13-subunit cytochrome c oxidase complex can result from mutations in several genes including the barcoding gene, COI. Without the COI protein, cells are unable harness usable energy from glucose. This is a jigsaw exercise. Students are assigned or choose one of four stakeholder parties. They meet in 'like' interest groups to become more familiar with that person's position and concerns. Afterwards, they meet in 'mixed' groups with a representative from each of the stakeholder groups. Students identify areas of agreement and disagreement, and propose a compromise to recommend to Congress regarding funding for rare disease research. In Lesson Seven, students learn how ***pediatric neurologists*** might use bioinformatics tools in their career.
8	**Exploring Bioinformatics Careers**	Students synthesize the information they have learned throughout the unit about people in various careers who use bioinformatics. Students then have the opportunity to perform independent research about a career of interest before developing a resume to use when applying for a bioinformatics-related job. Students then learn about writing cover letters. Optional extensions include peer-editing of resumes and a mock interview for jobs related to a career that interests them.
9	**Analyzing DNA Sequences and DNA Barcoding**	DNA sequencing is performed by scientists in many different fields of biology. Many bioinformatics programs are used during the process of analyzing DNA sequences. In this lesson, students learn how to analyze DNA sequence data from chromatograms using the bioinformatics tools FinchTV and BLAST. Using data generated by students in class or data supplied by the Bio-ITEST project, students will learn what DNA chromatogram files look like, learn about the significance of the four differently-colored peaks, learn about data quality, and learn how the data from multiple samples are used in combination with quality values to identify and correct errors. Students will use their edited data in BLAST searches at the NCBI and the Barcode of Life Databases (BOLD) to identify and confirm the source of their original DNA. Students then use the

		bioinformatics resources at BOLD to place their data in a phylogenetic tree and see how phylogenetic trees can be used to support sample identification. Learning these techniques will provide students with the basic tools for inquiry-driven research.
Wet Lab	**DNA Barcoding: From Samples to Sequences**	In this lesson, students perform the wet lab experiments necessary for DNA barcoding. Beginning with a small tissue sample, students purify the DNA, perform polymerase chain reaction (PCR) using COI-specific primer pools, and analyze their PCR products by agarose gel electrophoresis. PCR reactions that resulted in products of the correct size are subjected to PCR purification and submitted for DNA sequencing. This DNA sequence data can be used in Lesson Nine, or as part of an independent project.

Advisory Group

The third and final Bio-ITEST Annual Advisory Board meeting was held on October 6, 2011 at the University of Washington Medicine South Lake Union building. The Advisory Group is comprised of experienced lead teachers, research scientists (including Tim Rose, Ph.D., Professor in the Schools of Medicine and Public Health at the University of Washington, and Eugene Kolker, Ph.D., Chief Data Officer at Seattle Children's Research Institute), diversity experts, local bioinformatics experts (such as Todd Smith, Ph.D., Senior Leader at Perkin Elmer), leading researchers at our partner scientific institutions, bioethicists, Bio-ITEST leadership and evaluation teams, and education partners (including Maureen Munn, Ph.D., Director of Education Outreach for the Department of Genome Sciences at the University of Washington and PI of the ITEST *Strategies* grant, *Exploring Databases*).

The Advisory Group provides invaluable guidance on the development of the new teacher and student programs, the recruitment of participants, and the Bio-ITEST evaluation. The 2011 Advisory meeting focused on summarizing the key project developments of the previous year: the development of new career lessons and online resources, the two professional development workshops and teacher reunion held earlier in the year, our dissemination efforts at regional and national education conferences a and a webinar on Biosciences Careers with the ITEST Learning Resource Center, student research projects with DNA barcoding, and our first student workshop, "Dynamic DNA: Exploring Biological Systems," in partnership with the Institute for Systems Biology and DigiPen Institute of Technology.

The evaluation team summarized the findings from the Bio-ITEST research study and the exploratory study exploring the emerging role of science teachers in fostering STEM career awareness among students. Board feedback about these findings and avenues for dissemination and publication helped shape program goals for the remaining months of the project. Board members were particularly impressed with the magnitude of the impacts on student career awareness after instruction with the Introductory unit, *Using Bioinformatics: Genetic Testing,* and urged the team to pursue publication of the work in a peer-reviewed education journal, such as *Cell Biology Education (CBE) Life Sciences.* They also recommended disseminating the "Emerging Role of Science Teachers" study in a similar forum.

As this was the last time that the Board would meet as part of the Bio-ITEST project, Co-PI Karen Peterson, M.Ed., led the group in an exercise called “Envisioning Future Impacts.” The goal was to end the meeting on a positive note, and free ourselves from preconceived notions of program limitations by imagining how many people *could* be reached with our program if we had unlimited resources at our disposal. Examples included increasing visitors to our website, distance learning in all 50 states, and engaging in public policy changes in education at the national level. As a group we envisioned impacting 1,145,592 people with our program!

Collaborations and Partnerships

Collaborations and partnerships allow program staff to better leverage Bio-ITEST resources, creating a synergistic effect for teachers and students.

Seattle Aquarium
A cornerstone of the Student Research Project on DNA barcoding involves partnering with organizations that can provide samples for students to barcode. Further, these partnerships provide a scientific context for the barcoding samples, whether in the form of stories of where, how and why the samples were collected, or descriptions of the larger scientific programs of which these samples are already a part. Student interest and learning increases when students are engaged in “real world” science, as they know that their work matters and contributes to furthering the scientific enterprise. The Bio-ITEST program continued our work with Shawn Larson, Ph.D., of the Seattle Aquarium for the student research projects on barcoding. Samples provided by the Aquarium included biopsy samples from sixgill and sevengill sharks, giant squid, and local fish species. Teachers at the summer 2011 professional development workshop, “Using Bioinformatics: Genetic Research, and students working as interns for the Bio-ITEST program or in participating Bio-ITEST classrooms, are barcoding these samples and comparing their utility to other genetic markers. See the “Students as Citizen Scientists” section for more details.

National Oceanographic and Atmospheric Administration (NOAA)
Harriet Huber, Ph.D., and Pam Jensen, Ph.D., of the National Oceanographic and Atmospheric Administration (NOAA) have also provide barcoding samples for students, while serving as a model of collaboration for teachers around the country to build on. These samples include giant snails from the Berring Sea that are difficult for scientists to identify based on morphological characteristics. To learn more, and see pictures of these beautiful mollusks, see the “Students as Citizen Scientists” section of this report.

DigiPen Institute of Technology, Institute for Systems Biology, and the Lake Washington School District

In an effort to increase our reach to students directly, Bio-ITEST partnered with DigiPen Institute of Technology, including Bio-ITEST Advisory Board Member Ray Yan, as well as the Institute for Systems Biology's Dr. Nitin Baliga and Claudia Ludwig, and the Lake Washington School District to create a summer workshop for students in 2011. The 90-hour course, "Dynamic DNA: Exploring Biological Systems," provided students with experiences in systems biology and bioinformatics, with particular emphasis on genetic testing, penetrance, and the role systems thinking plays in understanding biology today. This course went beyond the scope of our original grant. For more information, see the "Reaching Students Directly" section of this report. Dr. Baliga and Ms. Ludwig also provided training for Bio-ITEST teachers in the use of their systems biology modules at the May 2011 Bio-ITEST Teacher Reunion, described in the "Professional Development for Teachers" portion of this report. This was the first opportunity of many for the NWABR and Bio-ITEST teams to assist the Baliga team in expanding the reach of their systems biology education programs to a wider audience of educators. Dr. Baliga also spoke directly with teachers at the summer 2011 Bio-ITEST professional development workshop about the value of integrating systems biology into secondary science classes.

Fred Hutchinson Cancer Research Center
For classes that lack wet lab facilities, Bio-ITEST staff will have partnered with Beverly Torok-Storb, Ph.D., Associate Head of the Clinical Research Division and Director of the student Training Lab at the Fred Hutchinson Cancer Research Center (FHCRC). Dr. Torok-Storb has made available her student training lab, which provides lab facilities to students under age 18 – a rare opportunity in many research facilities. This has allowed Bio-ITEST staff to work with students and teachers for barcoding projects, including accepting high school student interns to assist with barcoding experiments and preparation of barcoding "kits" for use in Bio-ITEST classrooms. One student of a summer 2010 Bio-ITEST teacher worked on an independent study project on DNA purification during the 2010-2011 school year. Another student from the "Dynamic DNA" summer course has been an intern in the lab since the beginning of the 2011-2012 school year. DNA from samples purified in the Training Lab and sent for sequencing is then provided to Bio-ITEST classes, allowing students to perform authentic data analysis.

Summary

The program has been successful in meeting Y3 goals related to program development and delivery consistent with the proposed timeline, including exceeding the original scope of the project by reaching students directly in our summer workshop, and disseminating curricular and career materials through two webinars. The curricular materials and the professional development we have provided fulfill a need for quality educational resources related to bioinformatics and STEM careers. Teachers have shown significant increases in their understanding of bioinformatics and the data-intensive nature of science today, as well as the importance of exposing their students to a variety of STEM careers. Students have found the curricular materials engaging and relevant, and demonstrated increased awareness of science careers and self-efficacy in using the tools of science. **To date, we have reached more than 350**

teachers through our workshops and presentations at professional development conferences. **Through the Bio-ITEST teachers who have participated directly in our professional development workshops this year, we have reached over 700 students.**

Plans

As the Bio-ITEST project draws to a close, we are in the process of finalizing the layout and graphic design of completed Introductory curriculum, *Using Bioinformatics: Genetic Testing,* and the Advanced curriculum, *Using Bioinformatics: Genetic Research.* The research and exploratory studies have been completed, and are currently being prepared for publication in a variety of education-related journals. It is our hope to continue the "Dynamic DNA" partnership and hold another summer workshop for students this year. We will continue to disseminate our curricular materials at regional and national education conferences and through our website, and plan to hold a final, one-week summer teacher professional development workshop for an additional 24 teachers.

Appendix

Advisory Board
Roster

Bio-ITEST Teachers
Participant Roster Feb 2011
Participant Roster Aug 2011
Summer 2011 Syllabus

Final Curriculum Overviews
Using Bioinformatics: Genetic Testing
Using Bioinformatics: Genetic Research

Evaluation Report
ITEST Final Report 2011: Evaluation of the Bio-ITEST Project