Be a Scientist, Do Practical Science:
Teachers Explore Marine Biotechnology and Bioinformatics

Steven J. McGriff
Assistant Professor
Department of Instructional Technology
San Jose State University
One Washington Square
San Jose, CA 95192-0076
smcgriff@email.sjsu.edu
408-924-3654

Descriptors: teacher education, instructional design and development

Presented at the annual conference of the Association for Educational Communications and Technology (AECT), Dallas, TX, October 11, 2006.

Be a Scientist, Do Practical Science: Teachers Explore Marine Biotechnology and Bioinformatics

Steven J. McGriff
Assistant Professor
Department of Instructional Technology
San Jose State University
One Washington Square
San Jose, CA 95192-0076
smcgriff@email.sjsu.edu
408-924-3654

Introduction

Science teachers in California are required to teach the state standard for inquiry-based science, molecular biology, genetics, and the role of technology and computer analysis in the study of biology. However, the field is changing so rapidly many teachers lack a clear understanding of how to do science using current technology and how to make the complexity of science relevant to their students. A three-week summer workshop, *Marine Biotechnology and Bioinformatics for Teachers*, was held in July 2006, at the California State University, Monterey Bay campus in California, where 13 middle- and high-school science teachers were paid a stipend and immersed in "doing science like scientists do." The teachers were from the San Francisco Bay Area, the California Central Coast, Southern California, and one traveled from Georgia to participate.

The workshop was a comprehensive project sponsored by the Information Technology Experiences for Students and Teachers (ITEST) program, established by the National Science Foundation (NSF) to address the looming shortage of technology workers in the United States (ITEST, 2006). Located around the California Central Coast, CSU Monterey Bay, Moss Landing Marine Labs, and San José State University collaborated to develop the workshop.

In a problem-based learning context within the field of marine biotechnology and bioinformatics, the teachers used current research methods for DNA extraction and analysis of mussels searching for an invasive species. They had a very positive response to doing rigorous science that took them out in the field and back to the wet lab. The workshop was designed with instructional strategies for rapid integration of new knowledge and best practices for transforming high-level, new science knowledge into lesson plans for students. Recommendations and future directions for the next two workshops are discussed.

Outdated Standards

California education standards for science content include planning and conducting experimental investigations in cell biology and genetics, including DNA sequencing. For many experienced teachers the technology and research methods have evolved since they were formally trained and the state standards have not kept pace. Many other science teachers have not had an in-depth exposure to the practice of scientific inquiry. This workshop was designed to begin a process for addressing the lack of current science standards involving technology.

California and National Standards

The California science standards include one high school standard for biotechnology, listed under Biology/Life Sciences, Genetics, and referenced as genetic engineering. There is no reference found in the California science or technology standards for bioinformatics (California State Board of Education, 1998). The subject matter experts for this workshop defined biotechnology as the use of biological processes to solve problems or make useful products. Bioinformatics is defined as the use of computers to store, retrieve and analyze biological data. Further searching for information technology yielded no result in the California standards. The national science education standards do not have a standard involving biotechnology, bioinformatics, or information technology and the word “technology” is not found in the 276-page document (1996).

Marine Biotechnology and Bioinformatics Workshop

Learning the nature of scientific inquiry is better suited for an extensive, three-week, immersive, hands-on workshop, where teacher participants can really get into doing what scientists do while conducting research. The goal of the workshop was to develop the teachers’ ability to assimilate high-level, scientific, and technological information and procedures, then break it down into teachable chunks suitable for the middle- and high-school students in their classrooms.

Marine biotechnology was used to gather data that could be analyzed using bioinformatics techniques. The field of marine biotechnology was chosen for the workshop because the principle investigators both specialized in marine biology. Information technology is best integrated with marine biology in the form of bioinformatics. The workshop theme was on presenting an authentic biotechnology problem for scientific inquiry: identifying an invasive mussel (*mytilus galloprovincialis)*, which can only be determined by examining DNA evidence using bioinformatics software.

It takes time to do science: harvesting mussels from the local waters of Monterey Bay, setting up wet labs on campus, running experiments, and analyzing data required numerous hours. To create a successful learning environment, it was decided to use an immersive, “hands-on, mind-on” model. A majority of the scheduled learning experience was devoted to knowledge acquisition and laboratory/field science practice in marine biology and biotechnology. The teachers were first given background information on the ecological problem this invasive species causes, then an explanation of the biotechnology processes that would enable them to investigate this problem. The second morning, the teachers collected mussels from a local pier and returned to the wet lab where they learned a series of procedures to extract and process the DNA.

Another significant portion of the schedule was reserved for learning to use bioinformatics software to manage the data analysis and sequencing of the DNA extracted by each participant in the laboratory. Early in the second week, the teachers used their DNA sequences that had been processed at an outside laboratory and began the analysis with software such as chromas, Blast, and Genbank.

The lesson plan development process was integrated throughout the first two weeks, overlapping the science and technology topics, and culminated in the lesson implementation in the third week. The design and development of the lesson plan component is presented in more detail in the next section. More information, resources, and materials about the Marine Biotechnology and Bioinformatics for Teachers Workshop can be retrieved from http://marinebiotech.net.

Workshop Design for Rapid Integration

This was the third year developing the workshop. The first two summer workshops were designed and developed by the two principle investigators based on their expertise with marine biotechnology and bioinformatics. Two instructional designers were brought onto the project in the third year to incorporate the lessons learned and develop innovative instructional solutions that would facilitate the transfer and application of knowledge to the teachers’ science classroom.

State standards were integrated in the workshop curriculum and explicitly taught so that teacher participants can more easily see how to incorporate them into their own science classrooms. The two principle investigators, who also served as instructors, used the latest science methods in a technologically advanced laboratory and computer lab.

Pedagogical issues for teaching science methods were addressed by having participants immersed in a problem-based learning (PBL) scenario derived from current marine biotechnology research that was being conducted at nearby Moss Landing Marine Laboratories, Moss Landing, CA. Going one step further, teachers were challenged with the requirement to transform their new knowledge into a lesson plan that could be realistically taught in their own science curriculum. It is generally accepted that a real demonstration of mastery is to teach someone. The NSF grant specified that teachers should be lifelong learners and willing to share their knowledge with their students, who were samples of the underrepresented population in STEM careers. The issue of transfer was a high priority for the workshop to help insure that the teachers' students would also benefit from learning about current science methods in biotechnology and bioinformatics, as well as careers in information technology.

Marine biotechnology and bioinformatics are two information intensive topics that could have easily taken the entire three-week workshop. The mandate from NSF to also teach lesson plan development created a pedagogical challenge. The two instructional designers worked with the two subject matter experts to develop a full 15-day workshop schedule to integrate all the three content areas and balance the goals of the workshop. Instructional strategies and planning were incorporated that would support and facilitate knowledge and skill acquisition of the specific scientific methods presented. In the workshop design, lesson plan development was introduced in the first week and overlapped the marine biotechnology and bioinformatics topics to allow the teachers time to think of how they would create a lesson plan based on what they were learning. It was expected that teachers would complete their workshop learning experience by writing a lesson plan that would be delivered in their own classrooms during the academic year. In addition, teachers were expected to work in teams to develop a lesson and teach it to a group of students in the last week of the workshop. To facilitate developing lesson plans for both purposes, half-day sessions were included to teach problem-based learning with Web Quests, as well as other instructional strategies. The two instructional designers taught these sessions and closely supported the teacher teams during the development phase.

Although science teachers working within the Central California Coast and San Francisco Bay Area regions were the target audience for this summer workshop, the second important beneficiary of the workshop were the underrepresented student groups whom these teachers serve. This student population, which comprises low-income Hispanics, Latinos, as well as a significant percentage of Asian and African-Americans, does not advance into careers in information technology or STEM careers (science, technology, engineering, and math) in proportion with their numbers. This issue causes extreme concern in light of the multitude of well-paying information technology jobs available in nearby Silicon Valley and the entire San Francisco Bay Area. To meet the grant requirement and provide teachers the opportunity to do a formative evaluation of their lesson plans, 20 local middle- and high-school summer students, who were a representative sample of the target student population were invited to participate in the workshop during the last week.

Transparent Instructional Systems Design

Other instructional technology related interventions used during the workshop were transparent to the teachers. For example, using a basic team-planning model, teachers formed their own lesson plan groups, chose a topic from the workshop, and collaborated with the other three groups to design an appropriate sequence for the four lessons. The lesson implementation process was a form of microteaching and included the Japanese Lesson Plan (Columbia) protocol (Chokshi, Ertle, Fernandez, & Yoshida, 2001), where the quality of the lesson was determined by observing the learners' reactions. Within the teacher teams, those who were not giving large group instruction conducted the observations. Further instantiation of instructional systems design occured in the development of templates for the lesson plan format and other instructional materials prepared by the techers. The lesson plan was based on Bernie Dodge's WebQuest model (Dodge, 2006) and incorporated additional placeholders for standards, assessment of learning outcomes, and STEM career options. The students who were invited to participate in the lesson provided each team with immediate feedback as evidenced from the products they produced during creative, reflective learning activities following each lesson. In addition, the students then participated in a group debriefing and completed an anonymous survey.

Formative evaluation, a vital component of the instructional design process, focused on the teachers' lesson plans and implementation:

1. Formative evaluation of the lesson confirmed the teachers application of knowledge
2. Written feedback from the student participants and the products they produced after the lesson helped the teachers know the degree of effectiveness of their lesson
3. Peer feedback using the Japanese Lesson Plan protocol informed the teachers of how well their lesson was holding the students' attention

Best Practices

The best practices for teaching complex science to teachers are summarized below:

- Make instructional technology strategies transparent to participants
- Use project-based learning immersion
- Allow participatory groups for responsible learners to share ownership of the learning environment and outcomes
- Integrate new science knowledge for later transfer by requiring teachers to develop a lesson plan during the workshop
- Practice the lesson plan, collect feedback, and revise it for improvement
- Use formative evaluation at 3 levels to achieve a more complete analysis: program, peer, and student.

To further reinforce transfer of knowledge after the workshop, the teachers were required to attend six follow-up seminars over the following academic year. These seminars were designed to provide pedagogical support for delivering the lesson in the teacher's classroom, teach emerging technology skills, and focus more in depth on STEM careers.

Results, Recommendations and Future Directions

Preliminary results from the workshop show the majority of teachers were very satisfied with the experience of doing science the way real scientists do. They liked collecting mussels using carefully controlled research procedures and processing the specimens under the watchful eyes of the marine biologist and her teaching assistants. They expressed satisfaction with the rigor of learning how to carefully handle wet lab equipment, chemicals, and specimen dissection tools.

Recommendations

- Continue to use marine biotechnology as the basis for the immersion experience allowing participants to "be scientists and to do real science"
- Continue incentives (stipend and follow-up seminars) to encourage high-levels of commitment and increased focus on the learning process
- Increase instructional support for learning the science content
- Increase instructional technology support for developing the lesson plans
- Allow more workshop time to write lesson plans
- Establish unstructured preparation time for lesson plan development, such as library visits, reflection, collaboration
- Control workshop implementation to minimize scope creep of one topic into the time allotted for another topic

Future Directions

Given the outdated science standards at the national and state level, the results of this workshop could form the basis for a plan to do a major rewrite of the science standards. In addition, the lesson plan products that will emerge from the three workshops could be used to initiate science curriculum reform that will integrate biotechnology and bioinformatics.

References

California State Board of Education (1998). *Content Standards*. Retrieved March 22, 2006 from http://www.cde.ca.gov/be/st/ss/scmain.asp

Chokshi, S., Ertle, B., Fernandez, C., & Yoshida, Makoto. (2001). *Lesson Study Protocol.* Lesson Study Research Group, Teachers College, Columbia University. Retrieved April 3, 2006, from http://www.tc.edu/lessonstudy/doc/Lesson_Study_Protocol.pdf

Dodge, B. (2006). *The WebQuest Page at San Diego State University.* Retrieved, March 28, 2006 from http://webquest.sdsu.edu/.

ITEST (2006). T*he Information Technology Experiences for Students and Teachers (ITEST) program, Learning Resource Center website. Retrieved*d October 5, 2006 from http://www2.edc.org/itestlrc/aboutresourcecenter.html.

National Committee on Science Education Standards and Assessment, National Research Council (1996). *National Science Education Standards*. Retrieved March 22, 2006 from http://www.nap.edu/catalog/4962.html