

Marine Biotechnology and Bioinformatics, 2005-2009

Final Project Evaluation

Executive Summary¹

I really learned a lot and I realized that I would want a career that involves working with DNA because it fascinates me a lot. I didn't know that much about mussels but I learned a lot.

- *A high school student participant*

Four California State University authorities² in marine sciences, biotechnology, bioinformatics, and instructional technology collaborated in developing an intensive, technology-rich, biotechnology and bioinformatics workshop and curriculum, Marine Biotechnology and Bioinformatics (MBB).³ The NSF-ITEST project draws from cutting-edge marine science research, authentic science practice, the latest biotechnology and bioinformatics techniques, and instructional technology to create a novel curriculum for secondary teachers and their students. The curriculum incorporates Science, Technology, Engineering, Math (STEM) strategies and approaches, and has demonstrated that it effectively engages and encourages youth from groups under-represented in STEM fields to prepare for IT and science careers.⁴

Scientific Foundation. A typical research cycle in a modern molecular biology or biotechnology laboratory seamlessly integrates information technology, computer software, computer-controlled instrumentation, and laboratory bench-top procedures. The MBB curriculum is a microcosm of this cycle and links directly to STEM careers.

Pedagogical Foundation. Project-based learning grounded each teacher's experience in using and developing hands-on lessons linked to the California Science Standards. In-person, on-line, and telephone technical assistance helped teachers implement their lessons. Each teacher's "spin-off" of the MBB curriculum is archived on the project website's Teacher Resource Center (www.marinebiotech.net).

Project goals included (1) developing an intensive marine science research experience and curriculum in biotechnology and bioinformatics for secondary-level biology teachers that can be adapted for use in Grades 7-12; (2) integrating educational technologies and STEM career awareness for high school students; (3) providing technical assistance and a web-based Teacher Resource Center (TRC) to support teachers in implementing the curriculum; and (4) disseminating the MBB curriculum to educators and faculty of pre-service teacher training programs. The evaluation reviewed each of these elements.

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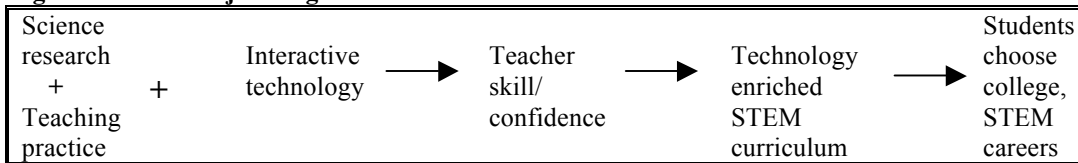
² The four included Simona Bartl, Ph.D., PI (Moss Landing Marine Laboratories, MLML), Henrik Kibak, Ph.D., co-PI (California State University Monterey Bay), Roberta Barba, Ph.D., co-PI and Steven McGriff, Ph.D., Instructional Designer (San Jose State University).

³ NSF ITEST grant 0525224, 2005-2009 extended the work begun in the successful ITEST pilot project (NSF grant ESI-0323175, 2003-2006).

⁴ Schacter, J. (1999) "Does Technology Improve Student Learning and Achievement? How, When, and Under What Conditions?" *Journal of Educational Computing Research* v. 20. www.milkenexchange.org

The **MBB Logic Model clarifies relationships** among project goals and activities and ITEST’s goal of increasing the numbers of students from underrepresented groups who choose these careers (Figure 1).

Figure 1. MBB Project Logic Model



Participants reflected demographics of California’s middle and high school biology teachers and students. Of the 39 teacher participants, most were female, between 22 and 50 years of age, increasingly ethnically diverse, and with limited experience in biotechnology and, especially, bioinformatics. High School students (N=20 each year) from two early outreach programs (RISE and Upward Bound) participated in an MBB marine biotechnology research intensive each summer.⁵

Evaluation Design

The **mixed method evaluation** assessed teachers’ science knowledge, attitudes and beliefs before and after the summer workshop. The desired goal was that teachers would score at least 70% on the final Content Assessment of biotechnology and bioinformatics, as evidence of mastery. Students completed short daily satisfaction surveys and a final survey about their overall experience at the end of the week.

Key Results

The **MBB Science curriculum** organizes a large amount of highly technical material into easily absorbed “kernel objects” (nuggets of information). The curriculum is both cognitively appropriate for adult learners and easily adapted for high school students. It is infused with instructional technology and incorporates the Technology Learning Cycle⁶ (TLC), career awareness, and California Science Standards.

Teachers

At posttest six times as many teachers demonstrated content mastery by scoring at least 70 percent (n=18, 46%) compared to pretest (n=3, 8%).

Group results (2006-2008) show that post survey scores were significantly different from pretest scores (p<0.0001). The magnitude of Cohen’s *d*, the measure of the practical effect of an intervention, is interpreted as exceptionally large (Figure 2).¹

⁵ College-bound youth participated through their outreach programs: Recruitment in Science and Education (RISE), a CSUMB-affiliated science and math enrichment program for low income and under-served youths living in the region and West Hills Upward Bound of Lemoore, CA.

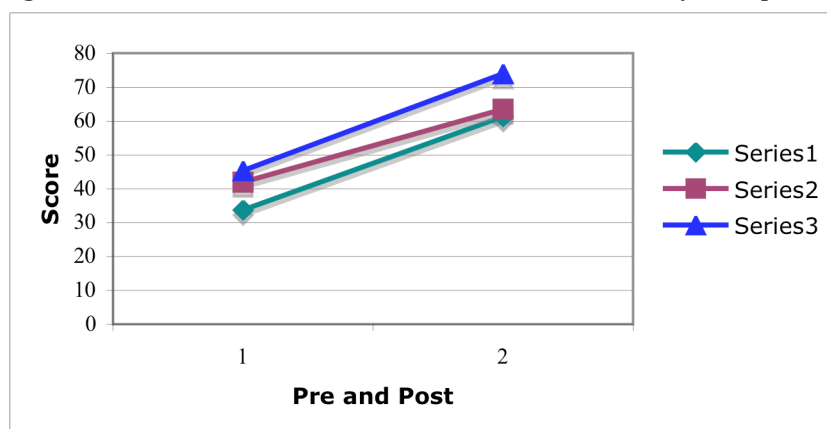
⁶ The four-stage Technology Learning Cycle models a confidence-building progression: (1) unfamiliar; (2) exploring, (3) personal/professional user; and (4) sharing/reflecting.

Figure 2. Content Test Scores: Mean (s.d.) at Pre and Post Test, t-test for difference between means, and effect size.

Year	N	Pretest Mean s.d.	Posttest Mean s.d.	t-test: difference between pre/post test	Effect size Cohen's <i>d</i>
2006	12	33.7 19.7	61.3 17.5	p<0.0001	1.48
2007	11	41.1 18.4	63.5 16.1	p<0.0001	1.25
2008	16	45.3 20.4	74.0 16.7	p<0.0001	1.54

The graph of pre and posttest means (Figure 3) shows that groups 1 and 3 (2006 and 2008) had similar improvement of 36% and 37%, respectively, based on Cohen's *d*, while improvement for Group 2 (2007) was a still respectable 30%. An ANOVA test for differences among groups was not statistically significant.

Figure 3. Content Test Scores: Pretest and Posttest Means by Group



At posttest teachers rated themselves, on average, as Personal/Professional users (3 of a possible 4 on the TLC scale) on most workshop dimensions, including biotechnology and bioinformatics content, biotech teaching, and teaching about STEM careers (Figure 4).

Figure 4. Post Survey Summary: Teacher Assessments of Summer Workshop (Grand mean)

Group	Biotech and Bioinformatics Mean, s.d.	Biotech Teaching Mean, s.d.	STEM Careers Mean s.d.	STEM Attitudes Mean s.d.	Science Teach- ing Attitudes Mean s.d.
2006	2.97 0.31	3.24 0.14	2.93 0.08	3.47 0.15	3.42 0.30
2007	2.77 0.23	3.00 0.23	2.70 0.11	3.41 0.10	3.35 0.23
2008	2.64 0.28	2.89 0.20	2.83 0.11	3.59 0.18	3.72 0.11

Students

STEM Careers. In addition to their hands-on experiences in the biotechnology and bioinformatics labs, students learned about potential careers in marine biology and biotechnology/bioinformatics from career-focused WebQuests, illustrated lectures, field trips to Monterey Bay Area Research Institute (MBARI) and MLML in Moss Landing,

and an annual field trip to an international pharmaceutical firm in Palo Alto. Students consistently preferred hands-on activities to lectures and demonstrations.

MBB student participants reported that their summer workshop experiences, such as collecting and dissecting marine specimens, viewing them under powerful microscopes, and collecting and analyzing DNA strongly influenced their career decisions. As RISE and Upward Bound mentors reported, students became more serious about their schoolwork, especially science, and volunteered to mentor and encourage younger students. One student committed himself to a career as a high school math teacher, and began tutoring younger students during the school year. Students responded positively to intensity of the experience, the excitement of doing hands-on science, and the intellectual satisfaction of obtaining useful answers to a scientific question.

Classroom Impact

MBB-trained teachers reach an estimated 6,000 students each year, year after year, in their own classrooms. The Student Surveyⁱⁱ and telephone interviews with selected teachersⁱⁱⁱ provided a window on these classroom experiences.

Middle School Students A total of 208 usable surveys from middle school students were submitted for the study, 124 from MBB teachers (MBB) and 84 from their colleagues who had not participated in the MBB program (COMP).

MBB students were more likely than COMP students to have used computers to learn about protein structure. MBB students were more likely than COMP students to have learned more about the daily tasks of people who work with DNA, about careers in information technology, about how DNA relates to real world issues, and about how to identify questions that DNA information can help to solve. They also reported a better understanding of what biotechnology and bioinformatics are, how to prepare DNA for analysis and how DNA is analyzed.

A Look Back: Six Teachers Reviewed their MBB Experiences.

The six teachers who reflected on their experiences since completing MBB were representative of their MBB colleagues in demographics and the range of their teaching situations. All of the teachers drew on their workshop experiences to develop and teach lessons using MBB content and techniques, including the use of authentic science strategies, biotechnology and bioinformatics, and instructional technology (WebQuests, wiki notebooks, a personal website, presentation software, and distance learning).

Teachers implemented segments of the curriculum with their students, meanwhile overcoming serious structural challenges, such as lack of ready access to computer- and wet-labs and restrictions on the use of web-based teaching resources. Teachers whose students had computers at home frequently assigned homework to extend classroom experiences. Their students often did more than required, exploring bioinformatics resources in depth. In contrast, tenth grade biology students who lacked skills in fractions and percentages were not likely candidates for biotechnology careers.

Summary of Findings

The MBB workshop became increasingly effective over the three-year funding period in response to teacher and student feedback and the formative evaluation.

- MBB met its goals of developing an effective, standards-based biotech/bioinformatics curriculum for teachers that integrated instructional technology and career components.
 - The *biotechnology* curriculum provided a focused, complete, and well-grounded authentic scientific experience with multiple opportunities for teachers to develop essential skills and knowledge within a standards-based conceptual framework.
 - Similarly, the *bioinformatics* curriculum focused on essentials. Participants with previous bioinformatics experience achieved mastery; neophytes were prepared to teach structured lessons from the project curriculum.
- **Teachers** mastered challenging scientific and technical information, developed and implemented lessons in their own classrooms and contributed to the project's web-based Teacher Resource Center. They recommended the Workshop to their friends.
- Teachers, more of whom had computer resources to implement bioinformatics lessons, observed that a technology-infused curriculum interested students and increased achievement.
- **Students** who participated in the intensive workshop developed career and college goals and mentored younger students.
- Students with MBB teachers knew more about biotechnology and science careers than students in comparison classes.
- Students were more interested and learned more from hands-on experiences in every instructional setting.
- Thoughtfully chosen instructional technologies, such as Clickers, Power Point, wikis, remote conferencing, and website design contributed to the learning experience.

The workshop schedule continued to evolve throughout the grant period. The 2008 sequence of three Saturday sessions in May, followed by the 14-day workshop in July, followed by four Saturday seminars during the school year (3, 14, 4) was more effective and more convenient for participants than previous configurations.

- The schedule provided time to build a stronger Science foundation; better met teachers' scientific goals for the workshop; contributed to increased enrollment and greater ethnic diversity; improved commitment, retention and collegiality; increased the number of experiences in marine science and with research institutions; and appeared to reduce stress.

The MBB website permanently archives the full curriculum, teachers' lesson plans, additional science and teaching resources, and project-related professional papers and talks, thus ensuring sustainability.

Recommendations

1. **From both a teaching and learning perspective, the 2008 workshop schedule (3, 14, 4) more effectively supported the project goals. It should be used in the future.**
2. **MBB should adopt participants' suggestions for program improvement:**
 - Infuse the MBB curriculum with thoughtfully chosen, instructional technologies, rather than creating a separate technology unit.
 - Fund on-campus housing for all teachers and high school students who enroll in the program so that they can participate more fully in all project activities.
 - Encourage teacher teams to participate as pairs and require applications to have a Principal's signature to increase the level of commitment.
 - Staff bioinformatics labs as well as biotechnology labs to ensure that lack of computer experience does not become an instructional barrier.
 - Provide expert review of participants' lessons to ensure accuracy before they are presented to students. The cutting-edge science is challenging, errors are easy to make and difficult to correct, once they have been taught.
3. **The STEM Career Component**
 - The instructional scaffolding for field trips has improved, but more can be done to make them more interesting and more useful to students in their career planning.
 - The television show, CSI, is enticing for many students because it provides a context for thinking about how to solve a complex scientific problem, contribute to justice, and right wrongs, all of which are important values for teens. Curriculum can help students consider these values as part of their career planning, and well as become more critical TV consumers.
 - ITEST should continue its emphasis on encouraging teachers to help students from diverse cultures learn about connections between school and STEM career opportunities.

ⁱ Cohen's *d* of 0.8 is commonly interpreted as showing that a treatment had a "large" effect. <http://www.uccs.edu/~faculty/becker/es.htm> accessed on 11/11/09 6:30 PM.

ⁱⁱThe Student Survey, a product of a collaborative process among the PIs, 2007 teacher participants, and the Independent Evaluator, was designed to capture evidence of greater understanding of topics related to the MBB curriculum among students of MBB teacher-participants compared to students in classes with non-participating teachers.

ⁱⁱⁱIn the spring of 2009, the evaluator conducted semi-structured telephone interviews with six of the 12 participants who responded to the PI's initial request and could be reached for follow-up.