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THE MOBILE REEF PROGRAM: A VEHICLE FOR SCIENCE LITERACY

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Abstract—The Santa Barbara Channel is a productive and diverse ecosystem that provides a rich resource for teaching toward science and environmental literacy. However, even though 98% of Santa Barbara and Ventura county schools lie within 15 miles of an accessible beach, close to 70% of the area's students had never been to the beach and knew very little, if anything, about the Channel Islands. Moreover, in recent years, there has been an alarming, downward trend in outdoor and informal science educational experiences. To address these concerns we used a mobile marine laboratory and pre- and post-classroom visit assessments to increase science literacy in local schools. By using a pre-visit assessment to determine levels of student knowledge of water, watersheds, and human impacts in watersheds, the Mobile Research Experience and Education Facility (REEF) Program was able to visit a class with the tools to address the identified weaknesses. Using touch tank aquaria and digital globe technology, students were taught specific science concepts related to state standards. Students then received a field trip to an educational aquarium. This had a twofold outcome. First, students were better informed prior to their "outdoor" experience. Second, having some pre-trip exposure to marine organisms enabled "first-time" visitors to the aquarium to have greater focus and improved learning. Comparison of pre- and post-assessment scores from 425 elementary and middle school students at five Ventura and Santa Barbara county schools showed a 22% increase in the understanding of the science concepts taught.

INTRODUCTION

Science is hands-on. It is messy, it begs questions, creates dialogue, uses math, is rich in history, and has an immense impact on society. And yet, as a society, our knowledge of science is lacking (NSF 2001). Furthermore, compelling arguments have been made that one cannot be science-literate without being ocean-literate (Strang et al. 2007). It would seem reasonable, then, that coastal communities should be more ocean-literate, based on proximity alone. Yet, in 2003, the Pew Ocean Commission reported the need to improve public literacy about oceans (Pew Charitable Trusts 2003). A 2005 poll of over 1200 individuals from coastal and non-coastal states revealed little difference in self-assessed level of knowledge with ocean and coastal policy issues (Steel et al. 2005). Another poll of 1106 citizens revealed a similar trend with regard to familiarity with terms and concepts associated with coastal and ocean management issues (Steel et al. 2005). Whereas approximately 50% of the respondents said they were somewhat informed with regard to ocean and coastal policy issues, only 10% said they were informed and 4% very well informed.

Santa Barbara and Ventura counties combined have four community colleges, two private colleges, one California State University, and one University of California campus. The two counties share a number of national parks and national forests, the Santa Barbara Channel Islands National Marine Sanctuary, as well as over 100 state and regional parks. They both have a number of major watersheds. Ninety-eight percent of the 255 schools in Santa Barbara and Ventura counties lie within 15 miles of an accessible beach. One would think, given the rich and diverse environment associated with the Santa Barbara Channel Islands, that science literacy, especially with relation to marine science, would not be an issue with regards to K-12 education. Yet, at many elementary schools in Santa Barbara and Ventura counties, science is all but absent in the classroom.

Exacerbating this apparent disconnect is a downward trend in visits by California school groups to institutions supporting informal science education. In an e-mail, which circulated amongst

marine educators on the listserv *OceanList*, feedback from teachers and informal educators around the country indicated that many other institutions were also experiencing a decline in school group attendance. Reasons for the decline fell into four categories: administrative, financial, staffing, and academic focus. We believe these factors could be further reduced, and potentially linked, to economics and/or academics.

The Marine Science Institute (MSI) at the University of California, Santa Barbara has developed one method for delivering effective, informal science education curriculum. For the past two decades the MSI has run a successful informal touch tank program serving approximately 5000 K–12 students annually. In the fall of 2004, MSI opened the Research Experience & Education Facility, also known as the REEF. The REEF is a teaching aquarium facility that serves as an informal science center for K–16 students and the general public in Santa Barbara and Ventura counties. Shortly after opening, REEF experienced a decline in visitation that echoed the findings discussed on *OceanList*, with many schools from Ventura County canceling their visits citing budget woes and the war in Iraq (Ventura has a number of military bases) as reasons for canceling.

The Mobile REEF, designed to fill the needs of schools that could not afford to visit the REEF, utilizes portable touch tanks and curriculum based on California State Science Standards to take marine science into classrooms. Through collaboration with the Santa Barbara Museum of Natural History Ty Warner Sea Center, a specially designed van was outfitted with the MSI Mobile REEF touch tanks, a 14" Magic Planet® from Global Imagination, and curriculum based on state standards and assessment tools modified from Kellogg Biological Station's Environmental Literacy Project to evaluate the outcomes of this project. Here we report how pre- and post-classroom assessment enabled us to address specific knowledge gaps and evaluate the effectiveness of classroom visits.

MATERIALS AND METHODS

Through classroom hands-on activities and inquiry-based questioning strategies, the Mobile REEF utilizes touch tanks and the Magic Planet® to

Table 1. Mobile REEF Program pre/post test questions adapted from Kellogg Biological Station's Environmental Literacy Project.

Question number	Questions presented to the students	Options
1	About what percentage of the Earth's surface is covered with water?	A. 30%; B. 55%; C. 75%; D. 90%
2	About what percentage of the water on Earth is fresh water?	A. 1%; B. 3%; C. 12%; D. 20%
3	Where is most of the fresh water on the Earth found?	Students list answers
4	What form is most of the fresh water on the Earth found?	Students list answers
5	Where do you think the water in the clouds comes from, and how does it get there?	Short answer
6	What are some factors that animals in a wetland have to adapt to?	Students list answers
7	Draw in mountains that act as watershed boundaries on the map below	Student provided with a diagram of rivers with tributaries draining into an ocean.
8	If a water pollutant is put into the river at town C, which towns (if any) would be affected by the pollution?	Based on diagram in Q7 with points A, B, C, D
9	Explain why only these towns would be affected.	Short answer

teach and assess students' grasp of California State Science Standards for grades 4–8. The program is designed to take place during a one-class period, which ranges in time from 50–65 minutes. Students are divided into two groups. Each group spends ~20 minutes at the touch tanks and 20 minutes at the Magic Planet® followed by a 10-minute summary. Assessments were administered to students by their teachers before and after the Mobile REEF visits to track the effectiveness of the program, and to identify misconceptions about watershed science that could be addressed during the classroom visit. Thus, specific topics covered in the classroom visit are determined by analysis of pre-assessment testing results. Assessment questions ranged from percent of planet covered in water, to an understanding of adaptations to wetland habitats (Table 1).

Touch Tanks

The Mobile REEF utilizes two, specially designed, 45-gallon (170 L) touch tanks with recirculation pumps and chillers to hold and exhibit local marine organisms. Students are first encouraged to handle and observe the various organisms. This is followed with a brief discussion, using graphics, to illustrate characteristics of the organisms' habitat(s). Students are then asked, based on grade level, to group the organisms based on morphology, adaptations to abiotic and biotic factors, or ecology. Students must support their conclusions with evidence gained during their observations and knowledge about the organisms' habitats.

The Magic Planet®

The topics for questions 1–4 were addressed, in class, utilizing the Magic Planet®, which gives students a 3-dimensional view of the planet accompanied by a diagrammatic review of the water cycle and development of hypothesis and visualization, based on real data, on the Magic Planet®. The digital projection globe contains visualized, moving, satellite imagery from astronomical, tectonic, and meteorological data supplied by NASA, NOAA, and others. First, based on pre-assessment results and through the use of a guided discussion using a chalkboard or dry eraseboard, students' knowledge of the water cycle and watersheds is assessed. Staff then use the globe's meteorological data with continued guided discussions to show the relationship between the water cycle and major geophysical features. Students are asked to develop hypotheses about where they might expect more/less precipitation and to support their hypotheses based on discussions. This is followed by a wrap-up discussion of the Earth's biomes and climate and the role that ocean circulation patterns play.

Following the activities at the touch tanks and the globe, students are led in an open-ended discussion based on each particular class' experience with the Mobile REEF unit. The discussion allows staff to address any persisting misunderstandings and/or misconceptions revealed in the pre-assessment or during the activities. Following the classroom visit, teachers administer the post-assessment to students, and the results are forwarded to Mobile REEF staff.

The Mobile REEF van visited 12 elementary schools, 4 middle/junior high schools, and 3 high schools in Santa Barbara and Ventura counties in 2006–2007. Post-assessment scores were compared to pre-assessment scores for 425 G4–8 students at 5 of the 12 schools visited.

RESULTS

Comparison of pre- and post-classroom visit assessments showed that student understanding improved for 7 of the 9 questions (Fig. 1). After the lesson, the understanding of where and in what form water is found improved by at least 20% (questions 1–4). The question regarding the source of water in clouds (question 5) showed no significant change between pre- and post-testing (>80% for both periods), and correct responses for the question regarding adaptation of wetland species (question 6) decreased by 17% between testing periods. The latter was the only question on which student understanding decreased after the classroom visit. A dramatic increase in understanding of watersheds (questions 7–9) was apparent after the lesson. Prior to visits, less than 17% could correctly draw the boundaries of a watershed (question 7), whereas after a visit approximately 66% were able to do so. Responses to both questions regarding routes of

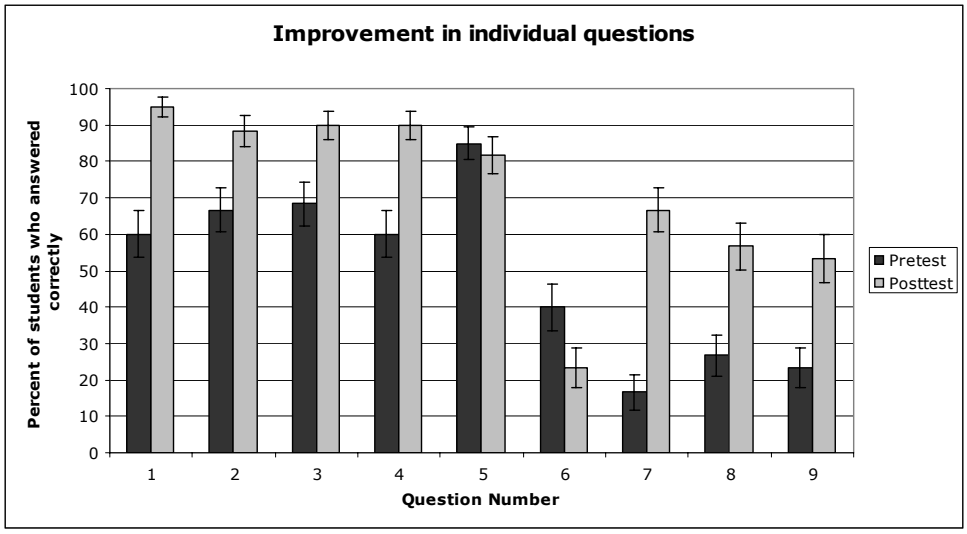

Figure 1. Change in percent correct responses, by question, between the Mobile REEF Program pre-test and post-test evaluation. Bars show mean correct responses with error bars. Questions are found in Table 1.

pollution (questions 8 and 9) improved by 30% between evaluations.

DISCUSSION

Incorporating pre- and post-classroom visit assessment showed that the Mobile REEF program improved student knowledge about key concepts, and facilitated the educational experience by allowing educators to address knowledge gaps. In this respect the Mobile REEF program serves as a model for other off-site environmental education programs, which could both increase and document their effectiveness by incorporation of such assessments.

It is instructive to examine the specific questions on which student performance did not improve. There was no significant change in the number of students correctly answering question 5, which assessed students' grasp of the water cycle by asking them to explain the origin of clouds. The lack of change could possibly be due to the difference between a slight variation in the pre- and post-assessment questions. Question 6, regarding wetland animals and their adaptations, was answered correctly by 17% fewer students after the classroom visit, and performance was low both pre- (40%) and post-classroom visit (23%). Students may have confused wetland animals with the rocky intertidal animals they saw in the touch tanks. Moreover, through diagnostic assessment it was determined that students that took the test prior to the lesson did not understand the diagram associated with questions 7–9. The dramatic improvement in those questions is attributed to the in-class lesson utilizing inquiry and guided discussion with students to re-create a similar diagram.

While the Mobile REEF was designed to teach to specific state standards, one of the most valuable lessons learned was what students in specific grades really know about topics in science, how they have arrived at that knowledge, and how to adapt the program *in situ* to respond to a specific groups understanding. For example, questions 7, 8, and 9 refer to mountains, urban development, and watersheds. Santa Barbara and Ventura are characterized by their Mediterranean climate. It has been assumed that, given our proximity to the ocean and mountains and the amount of urban development, students have a basic understanding of the ecosystem processes associated with the region. Theoretically, this should be further developed and supported by the high number of environmental organizations addressing watershed pollution. However, pre-assessment responses showed the contrary. During our visits, when students were given a drawing of our region, with mountains, lakes, rivers, urban development, and ocean, and asked to define a watershed, most

pointed to farm buildings, or stated that a watershed was a room ("shed") in which water was kept. Whereas hands-on classroom science experiences offered by programs such as Mobile REEF have a demonstrably positive impact on students' understanding of science topics, it is also clear that further research is necessary to develop assessments that get at the core of science curriculum literacy.

Finally, although only anecdotal at this point, staff from related programs (MERITO, LiMPETS, Ty Warner Sea Center, and the REEF) all have related that students exposed to the Mobile REEF Program were better prepared for the questions presented to them. It was further noted that students were more focused on topics and less affected by peripheral distractions (plant/animal movement/ contact, waves, etc.) associated with field experiences. This allows for these types of experiences to be truly educational, as opposed to "edutainment."

While it cannot address every misunderstanding and misconception, the Mobile REEF serves as a good model for supporting school science curriculum. The program's success extends to its ability to get students thinking in a logical, scientific manner, which prepares them for future hands-on experiences and other situations in which critical thinking is required. This approach could also be used to close other obvious gaps in student understanding on other critical science issues, such as the rate, scope, and impact of global climate change. Implementing methods to bring hands-on experiences to students at a time when schools are limiting off-campus activities is a major step toward maintaining high quality science education.

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