A Partnership Approach to Improving Student Attitudes About Sharks and Scientists

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*This article describes the methods and impact of a student–teacher–scientist research partnership on student attitudes. The partnership objective was to teach students about the diverse roles of sharks in the marine environment while personally connecting students with scientific study. Students (*N *= 229) participated in lessons about shark biology and helped the partnering scientist design experimental protocols and analyze data. A self-selected subset of students also volunteered (*n *= 82) for a field component working with live hammerhead sharks (*Sphyrna lewinii*). Student surveys before and after the partnership suggested that negative attitudes about sharks are due largely to lack of exposure, and direct attention to students' stereotypes about sharks resulted in significant attitude improvement. Change in students' attitudes toward scientists, however, was minimal. Students' negative views of scientists did decline significantly, but their overall views of scientists were relatively positive to begin with. Also of interest was the students' unremitting association of scientists with specialized equipment and the students' lack of personal connection to scientific ways of examining the world, suggesting that partnerships may be more effective at personally connecting students with scientific process if they explicitly incorporate activities designed to improve students' view of themselves as scientists.*

According to social cognitive theory, behavior is reflective of a person's attitudes, beliefs, and knowledge within a social context (Bandura, 1986; Zimmerman, 1983). Actions are a result of how beliefs interact with culture and society. In an educational context, social cognitive theory impacts students' motivation to study on a daily basis and motivation to pursue particular careers over the long term (Hammrich, 1997). Moreover, because student attitudes and perceptions are an integral component of their motivation to learn (Palmer, 2005), improving attitudes is critical for successful science education.

When prior knowledge is rooted in societal convention and in emotions, it can be very difficult to change attitudes. This is especially true with topics, like sharks, that elicit stress and fear. Successful intervention mechanisms for changing students' attitudes about such topics generally require longer time periods and experiential learning where students actively investigate their fundamental beliefs and construct new knowledge (Palmer, 2005; Phillips, 1995). Because of this, the educational utility of guest lectures or short field trips to view captive animal displays (such as aquaria and zoos) has been questioned by educators and by research scientists (Falk & Adelman, 2003; Tal & Morag, 2007). The tightening of captive animal regulations, especially with regard to elasmobranch species (i.e., sharks, skates, and rays), has further prompted science experts to question the value of captive animals for education (American Elasmobranch Society, 2004). And yet, short exposure to animals in captive environments is often the only opportunity students have to interact with these animals, which begs the question of (1) how to make short interactions meaningful and (2) how to rapidly evaluate the success of such interactions.

The Importance of Improving Students' Attitudes About Sharks

Changing students' attitudes about sharks is an important ecological concern. Sharks are a significant component of the aquatic ecosystem, yet they are being overfished at an alarming rate (Baum & Myers, 2004; Baum et al., 2003). Moreover, because public opinion of sharks is largely negative, there is a lack of concern regarding this ecological decimation of shark populations. Sharks are generally viewed as both dangerous to humans and as fishing competitors with humans (i.e., if there are fewer sharks eating fish, there will be more fish for humans to catch).

However, shark attack data and fishery models have shown that both of these concerns (fear and competition) are exaggerated. Given the numbers of people engaged in water activities worldwide, shark attacks are relatively rare. In most parts of the world, the probability of being attacked by a shark is statistically lower than the probability of being killed by a bee sting, killed by a car, or struck by lightning (International Shark Attack Files, 2008). In Hawaii, where this project was conducted, the probability of being attacked by a shark is less than one in a million, which is also less than the probability of being injured by a falling coconut (Hawaii Department of Land and Natural Resources, 2008).

On the other hand, the real and significant risk posed by sharks is the little-recognized fact that overfishing of sharks will result in an ecosystem-wide disruption. Ecological models have repeatedly demonstrated the importance of elasmobranchs in the ecosystem (see Schindler, Essington, Kitchell, Boggs, & Hilborn, 2002). For example, the depletion of sharks has recently been demonstrated to have cascading effects down the foodchain, from top-level predators to shellfish (Myers, Baum, Shepherd, Powers, & Peterson, 2007). In Hawaii, models show that the depletion of the tiger shark (*Galeocerdo cuvier*) population ultimately causes declines in tuna fish populations because tiger sharks are an important predator of juvenile seabirds, which in turn feed upon small tuna (Polovina, 1984). These examples demonstrate the integral role sharks play in the marine environment and show that decreasing shark populations will have undesired, and often unanticipated, effects. However, understanding and appreciating the role of these predators is obscured by the public's fears and myths about sharks, thereby posing a real challenge to enacting policies that will protect sharks and the overall ecosystem.

The Importance of Improving Students' Attitudes About Scientists

Part of the impetus for student–teacher–scientist partnerships is to increase student awareness about the nature of science and the process of scientific research so that students view science as accessible and connected to their daily lives. The need for this attitude shift in students is evidenced by researchers' surveys of students' attitudes. In the first documented study of high school students' attitudes about scientists, Mead [1] and Metraux (1957) found that students believed scientists to be lab coat-wearing old men of either tall-and-thin or small stature who work in a laboratory and are surrounded by glassware. As demonstrated by Chambers' (1983) study of 4,807 students and Thomas and Hairston's (2003) study of 757 students, students' current image of a scientist still includes a lab coat, eyeglasses, and facial hair (indicating mature male). Popular media has also brought a unique set of issues to bear on students' opinion of scientists; television shows such as Crime Scene Investigation (CSI) may help to dispel the stereotype of scientists as uncool and nerdy. But rather than making science accessible and personally relevant, the constant use of fancy equipment and stylishly dressed researchers perpetuates the misconception that science exists outside the realm of everyday experiences (Deutsch, 2006; Duncan & Daly-Engel, 2006; Willing, 2005).

Using a Partnership Approach

The purpose of this study was to investigate the utility of a student–teacher–scientist partnership model to alter students' attitudes and beliefs about sharks and to improve students' attitudes about scientists and doing science. It was hypothesized that although the intervention time was limited, the partnership approach would help students to improve their attitudes and dispel some of their stereotypic views about sharks and scientists by providing students the opportunity to (1) interact with a shark scientist; (2) learn more about sharks; and (3) participate as scientists in a shark research study.

A partnership model (Handler & Duncan, 2006) was used to couple scientific research goals with classroom work, guest teaching, and captive animal interaction. The partnership itself was a relatively short-term interaction comprising six class periods (one 90-minute class period per week for six weeks) combined with an optional field component. The goal was to maintain research integrity of the scientist's shark study while at the same time involving multiple teachers and a large number of students in the partnership. Six weeks was chosen as the duration for each student–teacher–scientist partnership because it was the amount of time needed to execute one shark research trial.

Methods

Science Education Partnership

This study was conducted as part of the National Science Foundation's Graduate Teaching Fellows in kindergarten–12th grade (GK–12) grant to the University of Hawaii at Mānoa's (UHM) Ecology, Evolution and Conservation Biology program. The grant provides fellowship support to enable science graduate students to partner with K–12 teachers and students in order to foster better communication, scientific teaching, and learning skills among all parties. At the UHM, GK–12 graduate students take part in courses to learn current science teaching pedagogy and then use their research as a basis for a partnership with a K–12 teacher. This partnership model enables authentic interaction, mutual mentoring, and collaboration (Baumgartner, Duncan, & Handler, 2006). And although the content of lessons in this study did not explicitly address attitudes toward scientists, the overall GK–12 partnership design is intended to effect shifts in students' attitudes about scientists.

In this study, the student–teacher–scientist partnership was based on the author's graduate research on the ability of scalloped hammerhead sharks (*Sphyrna lewini*) to convert food calories into body mass. Feeding experiments were used to estimate daily caloric requirements and conversion efficiency (Duncan, 2006). The maximum number of sharks that could be kept at a time was constrained to six because of space limitations, which necessitated consecutive feeding studies to obtain an adequate amount of data. The research protocol also required the sharks to be fed every day. This design allowed the completion of a full experimental sequence with sequential groups of students every two months. In true partnership fashion, the students' help genuinely contributed to the food conversion research study because multiple people were required for the feeding and weighing procedures.

The student–teacher–scientist partnership consisted of a GK–12 graduate student researcher (the author) who partnered with four teachers, and 229 students (from 15 different high school classes at four schools). The schools and teachers were selected based on responses to an advertisement placed in the Hawaii Science Teachers Association electronic bulletin. The primary qualification was that teachers be able to devote at least one classroom lesson per week for six weeks to the shark program. During the school year, the student component of the partnership comprised students from three public high schools (four 10th–2th-grade biology classes at one school, six 9th–12th-grade marine science classes at the second school, and four 9th–10th-grade general biology classes at the third school. During the summer, the student component of the partnership comprised one 10th–11th-grade class at a summer program. A subset of students (volunteers) from each of the school year classes and all of the summer program students also participated in the optional, after-school portion of the project, helping to conduct the experiment on live sharks.

Each of the schools represented different geographic areas on the island of Oahu, Hawaii. The first school is located in windward Oahu and serves rural and urban students (student body: N = 1,796, 28.2% free and reduced lunch). The second school is located in central Oahu and serves a spectrum of military and local students from a wide range of socioeconomic backgrounds (student body: N = 2,420, 12.0% free and reduced lunch). The third school is located in downtown Honolulu and serves a high percentage (22.8%) of families living in poverty (student body: N = 2,579, 59.2% free and reduced lunch; Hawaii Department of Education, 2008). The summer program is based at the Leeward Community College in central Oahu. It helps to prepare academically disadvantaged and low-income students for high school graduation and college (Leeward Community College Upward Bound Programs, 2008).

Learning Objectives

Lessons were taught to students during their normal classroom time periods (90 minutes) by the partnering scientist and/or by the classroom teacher. In most cases, the scientist would teach the lesson, talk about it with the teacher, and make modifications and then the teacher would teach the lesson to the next group of students while the scientist helped. The order of lessons and classes was rotated to (1) familiarize teachers with lesson content (for future use); (2) allow for interaction of the scientist with each class; and (3) promote feedback from the teachers to improve the scientist's teaching style and lesson content.

The primary objective was to improve students' attitudes about sharks, and lessons were designed to highlight common stereotypes that lead to negative opinions about sharks. For example, most people tend to view sharks as stereotypically big and grey with hefty fins and large teeth for eating sizeable animals. In reality, there are more than 400 species of sharks and more than 500 species of rays, and they exist in a wide range of shapes, sizes, and habitats. Some sharks are small and colorful (like the spotted wobbegong, *Orectolobus maculates*), whereas others are large but filter-feed on microscopic plankton (like the basking shark, *Cetorhinus maximus*). The first learning objective was to combat students' misconception about the stereotypical shark and help them to recognize the diversity and variety of shark and ray forms. The additional learning objectives were for students to identify the common elements of sharks and rays and to appreciate the vulnerability of individual sharks and shark populations.

The units of instruction were structured into four main lessons that were taught in the classroom (see

Appendix), including (1) *shark biology* where students learned about the anatomy and physiology of elasmobranchs; (2) *trophic levels and energy transfer* where students learned about the transfer of energy in the food web and the interconnectedness of the marine ecosystem; (3) *diversity of shark form and function* where students learned about the variety of sharks and how they are adapted to many different environments; and (4) *combining information about sharks from cultural legends and researcher data* where students looked at traditional knowledge, legends, and media portrayals and compared these pieces of information with what research studies have demonstrated about sharks.

Elements of scientific process and experimental design were also incorporated into the lesson sequence. Using a project-based approach, students worked through the process of designing a food conversion efficiency study. The students then graphed data collected from the real experiment being conducted by the scientist in cooperation with classmates who were participating in the optional, after-school field part of the study (see below). One of the points of emphasis during the lessons was that the students' participation in the study was part of a larger project; they knew about the other participating schools, and they often graphed more than one set of data to compare results between experimental trials.

Students who volunteered for the after-school field component at the Hawaii Institute of Marine Biology (HIMB) were selected on a first-come, first-served basis. They signed up for one day per week (e.g., Monday) and agreed to come to the HIMB for three hours every Monday for four weeks. Up to 12 students from each class were allowed to participate on a given afternoon, and 82 students (out of 229 total students in all classes) participated in the field component at the HIMB. During the field component, students helped feed and maintain the captive sharks. Students also collected data on individual sharks' food consumption, health, activity rate (tail beats per minute), and growth as well as data on water conditions (temperature and dissolved oxygen). Students volunteering for the field portion were either transported on a school-provided bus or provided their own transportation.

The volunteer, field portion of the partnership allowed the students and the teachers (each teacher visited the HIMB during the field portion at least one time) to observe living sharks in a captive environment and to be part of the research study. Juvenile sharks used in the research experiments were captured prior to student involvement. The sharks were then held in controlled, captive tanks to acclimate them and prepare them for the feeding trials. During feeding trials, the student volunteers were responsible for feeding the sharks specific daily rations (from 1.5% of their body weight to all they could eat). During the experiment, students measured sharks' weight change, daily intake, and activity rates. The field component provided an opportunity for hands-on experience with experimental procedures and data collection. It was also an opportunity for students to observe the fragile nature of a living hammerhead shark, which, like most sharks, is very fragile and easily harmed by human contact or environmental disturbance.

Attitude Assessment

In order to assess students' attitudes about sharks and scientists, students were given pre and post surveys asking them to "list the first five words that came to your mind when you think of the word *shark* and the word *scientist*." Lists of words were used as a tool to gauge students' ideas about sharks and scientists. This method was used as a proxy for other well-established assessment methods, such as the draw-a-scientist test (Mead & Metraux, 1957) where students' conceptions and attitudes are evaluated through drawings. Although the draw-a-scientist test has a long history and is a reliable metric (see; Finson, 2002; Fort & Varney, 1989; Mason, Kahle, & Gardner, 1991 among others), there is not a standardized protocol for evaluating shark drawings. In addition, drawing tests can be time consuming and can overemphasize stereotypes because of the limitations of what people tend to draw, especially in the case of sharks, which are difficult to draw accurately, even for experts in the field. Therefore, words were considered a more effective vehicle for illuminating students' impressions. The use of first-impression words allowed students to write things they could not draw, and they could complete the survey relatively rapidly, which was an important concern in our time-limited interaction. Additional support for the use of words as a measure of attitudes comes from a recent study of patrons' experiences at zoos and aquariums in which patrons' first-impression words in response to the phrase "Zoo—conservation" or "Aquarium—conservation" were used as part of an analysis of attitudes on conservation in zoos and aquariums (Falk et al., 2007). First-impression words were similarly

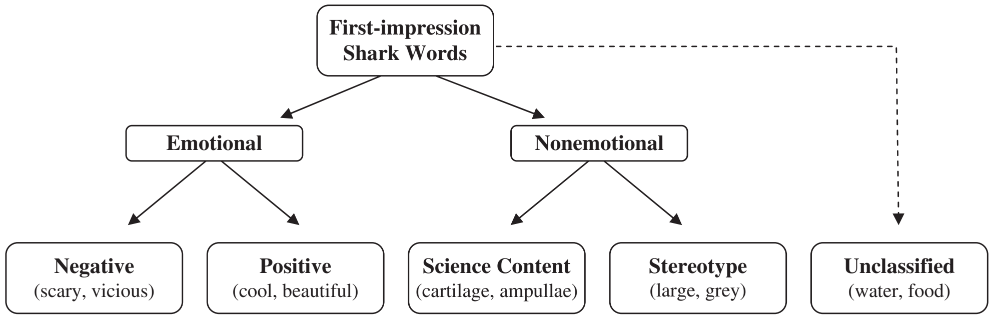

Figure 1. Flowchart used for separating shark words reported in student surveys into themes. Words were first separated by emotional versus nonemotional descriptors. Emotional words were then separated into negative and positive. Nonemotional words were separated into science content and stereotype. Words not clearly assignable were considered unclassified. Examples of commonly used words in each category are shown in parentheses.

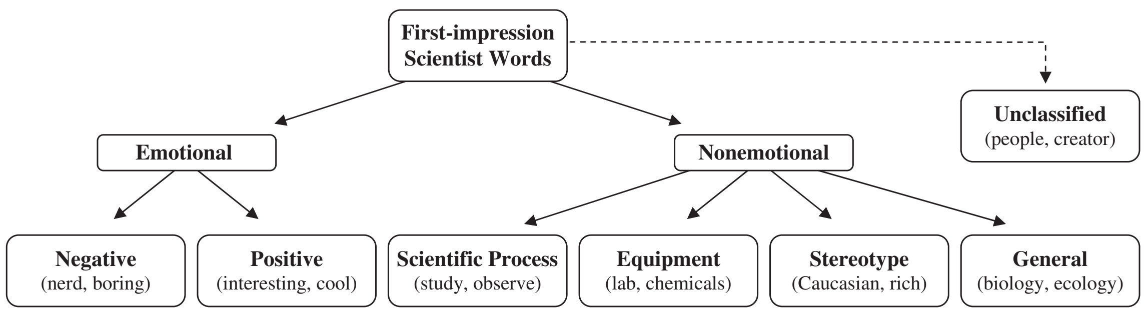

Figure 2. Flowchart used for separating scientist words reported in student surveys into themes. Words were first separated by emotional versus nonemotional descriptors. Emotional words were then separated into negative and positive. Nonemotional words were separated into scientific process, equipment, stereotype, and general. Words not clearly assignable were considered unclassified. Examples of commonly used words in each category are shown in parentheses.

used in a study of students' beliefs about the process of natural selection in evolution (Baumgartner & Duncan, 2009).

The words listed by students in this study were tallied in a database, and a content analysis was conducted to develop themes reflective of the words. The division of words into themes was independently reviewed by four researchers, who then convened to discuss and resolve differences. This process was systematic so that no one researcher had more input than others, and there was plenty of opportunity for revision to ensure that word groups were as accurate and impartial as possible. After establishing themes, a flowchart was constructed to facilitate the sorting of words (see Figures 1 and 2).

According to the flowchart generated using the themes, words associated with sharks were first separated by emotional (e.g., scary and cool) versus nonemotional (e.g., cartilage and large) categories. Within the emotional category, words were further segregated into negative (e.g., scary) and positive (e.g., cool). Within the nonemotional category, words were further segregated into scientific content target words (e.g., cartilage) that represented accurate representations of sharks targeted in the lessons and stereotype words (e.g., large) that represented concepts often associated with sharks but that are not truly representative of the group as a whole (these were items specifically targeted in the lesson plans as conventional stereotypes about sharks). The category of unclassified was used for words that were ambiguous or not clearly assignable to a category (e.g., water) (see Figure 1).

Words associated with scientists were sorted into themes using a similar flowchart. Students' words associated with scientists were first separated by emotional (e.g., boring or interesting) versus nonemotional (e.g., experiment or biologist). Within the emotional category, words were further segregated into negative (e.g., boring) and positive (e.g., interesting). Within the nonemotional category, words were further segregated into words dealing with scientific process (e.g., experiment), equipment (e.g., chemicals), stereotyped views of scientists (e.g., white), and science content (e.g., biologist). The category of unclassified was used for words that were ambiguous or not clearly assignable to a category (e.g., people) (see Figure 2).

In addition to survey data, anecdotal evidence was collected to assess students' attitude shifts. Students from one of the partnering classes ($n = 31$) were asked to write a short comment about their experience in the shark research partnership. These comments were collected and analyzed to validate the meaning ascribed to the students' use of first-impression words in the pre and post surveys. Students' comments were read and a content analysis was conducted to develop themes reflective of the comments. After establishing themes, comments were sorted and tallied. Comments and observations made by teachers were also collected in order to assess the effect of the partnership on students' attitudes.

Results

Survey Data

The students ($N = 229$) used a total of 1,128 words to describe sharks in the pre surveys and 939 words to describe sharks in the post surveys. Of the five theme categories established for shark words (negative, positive, science content, stereotype, and unclassified, the two largest categories both pre and post survey were negative and stereotype (Table 1). Paired pre to post comparisons showed significant decreases in negative words ($p = .002$) as well as significant increases in positive words ($p = .023$) and science content words ($p < .0001$). The other categories did not show significant changes (see Figure 3).

Students used a total of 1,065 words to describe scientists in the pre surveys and 909 words to describe scientists in the post surveys. Of the seven theme categories established for scientist words (negative, positive, equipment, stereotypes, education, science content, and unclassified), the three largest categories both pre and post survey were equipment, positive, and science content (Table 2). The difference in student responses about scientists pre and post survey was not as dramatic as the difference in students' responses about sharks. There was a statistically significant decrease only in negative words ($p = .002$). No other categories demonstrated significant changes, and students' general attitude toward scientists remained relatively constant (see Figure 4).

Anecdotal Data

Shifts in student attitudes about sharks were apparent in student behavior and in written comments. Students expressed concern for the well-being of the live sharks, and they also expressed surprise at how fragile live sharks actually are. In the post-project comments collected from a subset of students (one class, $n = 31$), four expressed a newfound desire to major in marine science, seven described the partnership as an experience of a lifetime, and eight said that they had liked learning. Twelve of these students also specifically stated that their attitudes about sharks had changed. Examples of these comments about attitude shifts include

> *I also got a chance to really understand the sharks and their behavior. I realized that not all sharks are harmful. You helped me realize that, so now not all the time I could be afraid of sharks.*

> *I think I changed my mind about sharks now because I am looking at sharks in a different way makes me realize that they are not that harmful to us, but are harmful if you harm them.*

> *I now know that sharks can be nice too, it's just that I perceived them in a different way because of what I hear on the news.*

> *At first I thought sharks were mean and vicious, but now my perspective has changed a whole lot. . . . I will successfully take this knowledge and pass it on to my fellow friends and family.*

> *To tell you the truth, I was able to also teach my brother that sharks are not really all scary. Although it was kind of hard to explain, but I was able to see myself loving sharks. Now I know that they're also like other animals and us.*

Teacher comments also indicated that the students were highly engaged in the partnership project. One teacher partner commented of the animal tagging activity (see Appendix for a description of activities), "I really like this. They (the students) are actually THINKING (emphasis teacher's). It is really hard to

Table 1
*Shark Words Used by Students in Pre and Post Surveys**

Shark Words	Total	Total Pre	Total Post	Difference	Pre %	Post %	Difference	*t*-test *p* Value
Negative	608	407	201	−206	36.1	21.4	−14.7	.002
Scary/spooky/ fear/afraid	162	98	64	−34	8.7	6.8	−1.9	
Dangerous	86	60	26	−34	5.3	2.8	−2.6	
Blood	60	37	23	−14	3.3	2.4	−.8	
Killer/kill-eat people	53	44	9	−35	3.9	1.0	−2.9	
Vicious/mean/fierce/evil	47	33	14	−19	2.9	1.5	−1.4	
Dead/deadly/death	39	27	12	−15	2.4	1.3	−1.1	
Attack	36	25	11	−14	2.2	1.2	−1.0	
Bite	23	15	8	−7	1.3	.9	−.5	
Aggressive	14	9	5	−4	.8	.5	−.3	
Hurtful/harmful	10	7	3	−4	.6	.3	−.3	
Crazy	8	7	1	−6	.6	.1	−.5	
Don’t swim/swim away/get out of water	8	5	3	−2	.4	.3	−.1	
Ugly	7	4	3	−1	.4	.3	.0	
Mischievous/cunning/sneaky	7	4	3	−1	.4	.3	.0	
Other	48	32	16	−16	2.8	1.7	−1.1	
Positive	237	98	139	41	8.7	14.8	6.1	.023
Cool/rad/sweet	45	22	23	1	2.0	2.4	.5	
Strong/powerful/tough	37	18	19	1	1.6	2.0	.4	
Smart/intelligent	33	7	26	19	.6	2.8	2.1	
Interesting	14	6	8	2	.5	.9	.3	
Awesome/amazing/exciting/wonderful	13	6	8	2	.5	.9	.3	
Beautiful/cute/pretty	12	5	7	2	.4	.7	.3	
Unique/special	8	0	8	8	.0	.9	.9	
Friendly/playful/nice	8	3	5	2	.3	.5	.3	
Amakua (family spirit)/Hawaiians	7	2	5	3	.2	.5	.4	
Other	59	29	30	1	2.6	3.2	.6	
Science content	283	82	201	119	7.3	21.4	14.1	.000
Fish	48	23	25	2	2.0	2.7	.6	
Big and small/different shapes	22	3	19	16	.3	2.0	1.8	
Swim/swimmers	20	11	9	−2	1.0	1.0	.0	
Cartilage/no bones	19	1	18	17	.1	1.9	1.8	

Table 1, Continued

Shark Words	Total	Total Pre	Total Post	Difference	Pre %	Post %	Difference	*t*-test *p* Value
Different types/diversity/variety	17	1	16	15	.1	1.7	1.6	
Rough skin/sandpaper	16	8	8	0	.7	.9	.1	
Fins	16	8	8	0	.7	.9	.1	
Specific part (e.g., heterocercal tail/ampullae)	16	0	16	16	.0	1.7	1.7	
elasmobranch	13	0	13	13	.0	1.4	1.4	
Specific type of shark (e.g., cookie cutter shark)	13	1	12	11	.1	1.3	1.2	
5–6 gills/open gills/gills	10	1	9	8	.1	1.0	.9	
Different colors/counter shading/camouflaged	8	0	8	8	.0	.9	.9	
Smooth/sleek	7	3	4	1	.3	.4	.2	
Other	58	22	36	14	2.0	3.8	1.9	
Stereotype	679	405	274	−131	35.9	29.2	−6.7	.059
Big/huge/large/long	192	120	72	−48	10.6	7.7	−3.0	
Teeth/large teeth	148	79	69	−10	7.0	7.3	.3	
Sharp teeth	86	57	29	−28	5.1	3.1	−2.0	
Fast	66	37	29	−8	3.3	3.1	−.2	
Predator/hunter	40	27	13	−14	2.4	1.4	−1.0	
Jaws/mouth	40	24	16	−8	2.1	1.7	−.4	
Gray	37	21	16	−5	1.9	1.7	−.2	
Meat eaters/carnivore	28	16	12	−4	1.4	1.3	−.1	
Great white shark	18	8	10	2	.7	1.1	.4	
Other	24	16	8	−8	1.4	.9	−.6	
Unclassified	260	136	124	−12	12.1	13.2	1.1	.585
Ocean/water	85	52	33	−19	4.6	3.5	−1.1	
“Jaws”	28	14	14	0	1.2	1.5	.2	
Hungry	17	9	8	−1	.8	.9	.1	
Food	9	2	7	5	.2	.7	.6	
Other	121	59	62	3	5.2	6.6	1.4	
Total words	2,067	1,128	939					

* *t*-test analysis of paired pre–post samples used percent within classes rather than the overall percent shown here. Words used less than seven times are grouped as “other.”

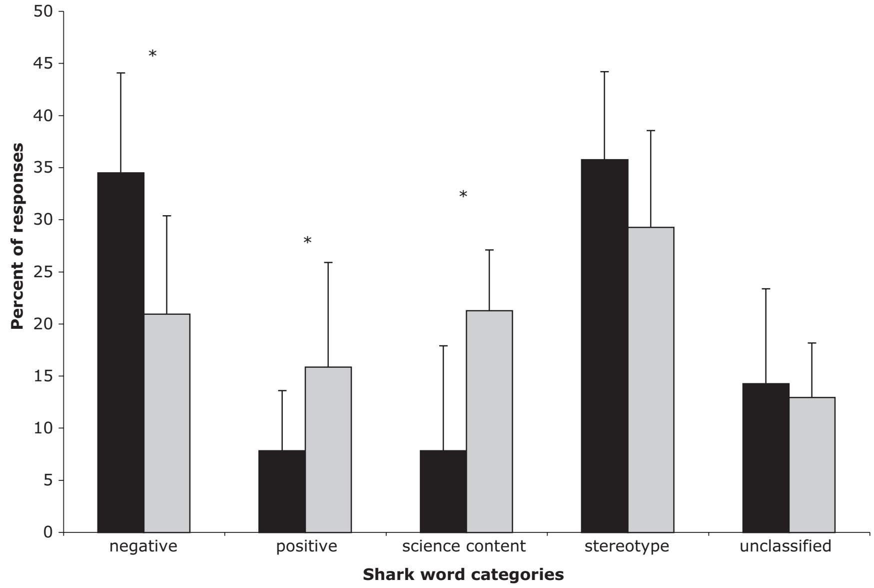

Figure 3. Relative frequency of shark words reported in student surveys. Black bars indicate the mean percent of responses by class for each category in pre surveys. Gray bars show post survey values. Error bars show standard deviations. Asterisks indicate categories with statistically significant differences between pre and post surveys ($p < .05$) in a paired t-test.

get them to think for themselves." Another teacher partner commented that student attendance was noticeably higher on days when the "shark lady" was scheduled to be in class. In addition, the teachers pointed out that the students who volunteered for the optional portion included students characterized as scholastically low-achieving. In fact, students who were low-performing in their classroom settings were often very competent in the field component.

Conclusions

Misconceptions About Sharks Corrected Through Exposure to a Wide Variety of Sharks

This student–teacher–scientist partnership project had demonstrable, positive effects on students' attitudes about sharks. At the end of the lesson sequence, students were more positive about sharks and they used more sophisticated scientific language in their first-impression words, which is an indication of increased content knowledge. In addition, anecdotal evidence indicated a desire among students to share their newfound knowledge with family and peer groups. Although this anecdotal evidence comes from a subset of participants and does not provide conclusive evidence of attitude shifts, it does help to validate the meaning ascribed to the first-impression word analysis and to give insight into the thoughts of student and teacher participants that was not discernable through the students' surveys alone. The anecdotal evidence presented here was also typical of comments made by students from all schools throughout the partnership.

This significant improvement in students' positive attitudes about sharks was encouraging, especially given the relatively short duration of the interaction (six class periods and four optional field experiences). This finding supports research in informal education settings (see Falk et al., 2007 and references therein), which suggests that brief exposure to novel experiences (such as zoos and aquaria) can impact students' attitudes and have lasting benefits. Therefore, the establishment of future short-term partnerships between science researchers and K–12 students and teachers appears to be a viable mechanism for influencing student attitudes, although there are limits to the influence that such partnerships may have.

The success of this particular partnership in shifting students' attitudes, for example, was likely influenced by the fact that many students' negative attitudes were rooted in a lack of exposure to different types of sharks, making it possible to directly address their gap in knowledge during the short intervention. For example, students were generally unaware that sharks and other elasmobranchs exist in a variety of sizes

Table 2
*Scientist Words Used by Students in Pre and Post Surveys**

Scientist Words	Total	Total Pre	Total Post	Pre %	Post %	Difference	*t*-test *p* Value
Negative	157	101	56	9.5	6.2	–3.3	.003
Nerd/geek/dork	26	22	21	2.1	2.3	.2	
Hard work	23	16	7	1.5	.8	–.7	
Boring/serious/no fun	20	16	4	1.5	.4	–1.1	
Insane/crazy/mad/madness	19	17	15	1.6	1.7	.1	
Know-it-all/smarty pants	8	6	2	.6	.2	–.3	
Weird/freak	8	3	5	.3	.6	.3	
Other	39	27	12	2.5	1.3	–1.2	
Positive	491	262	229	24.6	25.2	.6	.462
Smart/intelligent/bright/genious	310	169	138	15.9	15.2	–.7	
Interesting/fun	31	10	21	.9	2.3	1.4	
Hard working	20	11	9	1.0	1.0	.0	
Creative/skillful/talented/gifted	18	12	6	1.1	.7	–.5	
Cool/cool nerds	16	6	10	.6	1.1	.5	
Nice/friendly/caring/helpful	15	7	8	.7	.9	.2	
Brave/bold/fearless	11	6	5	.6	.6	.0	
Unique/one of a kind	11	7	4	.7	.4	–.2	
Other	59	29	30	2.7	3.3	.6	
Scientific process	623	326	297	30.6	32.7	2.1	.892
Study/studies/tests	113	72	41	6.8	4.5	–2.3	
Experiment	108	51	57	4.8	6.3	1.5	
Research/researchers	71	32	39	3.0	4.3	1.3	
Discoveries/discovery	29	14	15	1.3	1.7	.3	
Hypothesis/predictions	28	15	13	1.4	1.4	.0	
Curious/inquisitive	25	12	13	1.1	1.4	.3	
Exploring/explorer/adventurer	25	16	9	1.5	1.0	–.5	
Observe/observation	22	15	7	1.4	.8	–.6	
Learner/ready to learn/learning new stuff	20	9	11	.8	1.2	.4	
Knowledgeable/knowledgeable about research	17	12	5	1.1	.6	–.6	
School/classes/education	17	6	11	.6	1.2	.6	

Table 2, Continued

Scientist Words	Total	Total Pre	Total Post	Pre %	Post %	Difference	*t*-test *p* Value
Data	14	6	8	.6	.9	.3	
Inventors/inventing	12	9	3	.8	.3	−.5	
Thinking/thinkers/hard thinker	10	6	4	.6	.4	−.1	
Teacher/professor	10	5	5	.5	.6	.1	
University/college/college graduate	10	5	5	.5	.6	.1	
Evaluator/evaluate/analyze	9	4	5	.4	.6	.2	
Method/procedures/conclusion	7	2	5	.2	.6	.4	
Other	76	35	41	3.3	4.5	1.2	
Equipment	438	239	198	22.4	21.8	−.7	.554
Lab/lab work	96	50	46	4.7	5.1	.4	
Lab coat/white coat/apron	73	44	29	4.1	3.2	−.9	
Chemicals	63	41	22	3.8	2.4	−1.4	
Glassware (beaker, test tube, etc.)	37	20	17	1.9	1.9	.0	
Goggles	32	16	16	1.5	1.8	.3	
Science equipment	32	23	9	2.2	1.0	−1.2	
Microscope	25	14	11	1.3	1.2	−.1	
Math/formulas/equations	17	9	8	.8	.9	.0	
Tools/measuring tools/scale	16	5	11	.5	1.2	.7	
Technology/high tech/electronics/computer	10	5	5	.5	.6	.1	
Other	37	12	24	1.1	2.6	1.5	
Stereotyped persona	137	75	62	7.0	6.8	−.2	.648
Rich/has money/takes money	20	12	8	1.1	.9	−.2	
Glasses (wears them)	58	32	26	3.0	2.9	−.1	
TV/movie (Hulk, Star Wars, Doom, etc.)	16	8	8	.8	.9	.1	
White/Caucasian	7	3	4	.3	.4	.2	
Purple fluid/potion/explosions	7	4	3	.4	.3	.0	
Other	29	16	13	1.5	1.4	−.1	
General science	91	40	51	3.8	5.6	1.9	.597
Type of scientist (biologist, chemist, geologist, etc.)	20	10	10	.9	1.1	.2	
Ocean	9	7	2	.7	.2	−.4	

Table 2, Continued

Scientist Words	Total	Total Pre	Total Post	Pre %	Post %	Difference	*t*-test *p* Value
Name of scientist (author)	8	0	8	.0	.9	.9	
Other	54	23	31	2.2	3.4	1.3	
Unclassified	38	22	16	2.1	1.8	−.3	.933
People	8	6	2	.6	.2	−.3	
Other	30	16	14	1.5	1.5	.0	
Total words	1,975	1,065	909				

* *t*-test analysis of paired pre–post samples used percent within classes rather than the overall percent shown here. Words used less than seven times are grouped as "other."

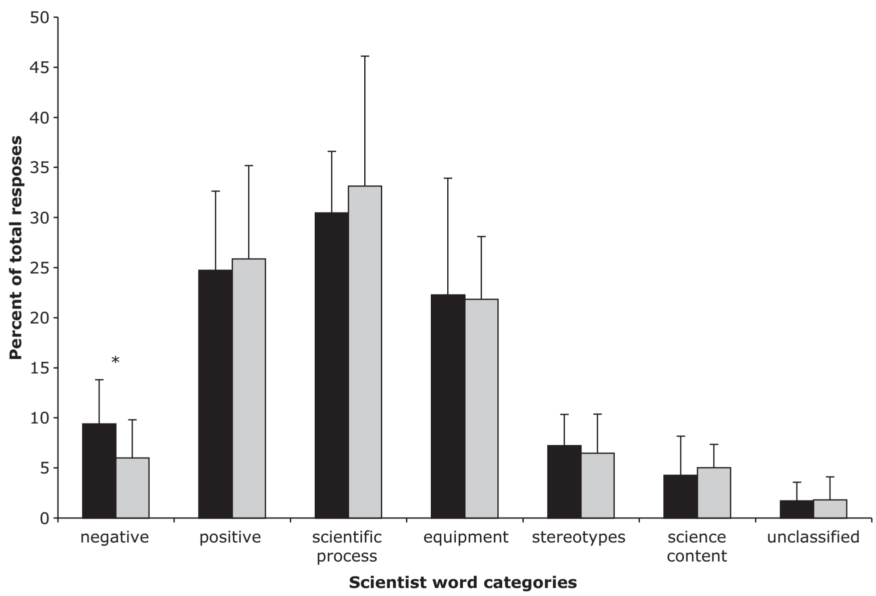

Figure 4. Relative frequency of scientist words reported in student surveys. Black bars indicate the mean percent of responses by class for each category in pre surveys. Gray bars show post survey values. Error bars show standard deviations. Asterisks indicate categories with statistically significant differences between pre and post surveys ($p < .10$) in a paired *t*-test.

(from a few centimeters to over three meters), colors (from grey to blue spotted), and lifestyles (from active predators to plankton filterers). Students were also generally unaware that even large, dangerous sharks are very fragile creatures. Through the in-class lessons, students were exposed to a variety of shark species. And, through field activities, some of the students experienced the vulnerability of sharks firsthand. Invariably, the fragile nature of sharks also became a classroom discussion topic; students were surprised that real-life sharks were vulnerable to human interaction—even when humans were trying to take good care of the sharks (i.e., in captivity). The success of students' attitude shift about sharks therefore appears to be partly a result of the relative ease of expanding their prior conception of sharks as large, grey robust creatures when they were exposed to sharks with a variety of shapes, sizes, and colors, which necessitated a restructuring of their shark stereotype.

Despite the success in attitude shift toward positive feelings about sharks, students' post surveys continued to indicate a high proportion of fear of sharks and thoughts associated with eating and teeth. The difficulty in influencing students' feelings of fear was likely due to the deep-rooted nature of these fears. Additionally, because sharks can truly be dangerous, these stereotypes and fears are not born entirely of misconception. Thus, the inability to significantly alter students' fear of sharks is not surprising. Indeed, the difficulty in attempting to alter students' perspectives about sharks has an interesting philosophical basis. It is important to allow a healthy level of fear while at the same time helping students to understand the ecological value of sharks. In other words, the educational goal was to help students improve their attitudes toward sharks in such a way that the relative danger associated with sharks was put into perspective so that the students can act as thoughtful, informed citizens rather than irrational ones. The students' expression of concern for sharks' well-being and positive feelings toward sharks in their anecdotal comments (see student quotes above) indicate that the partnership program successfully reached at least some students on an intimate, emotional level. Nevertheless, the students' fear of sharks is something that might have required more prolonged exposure to fully address. On the other hand, the large number of student responses that dealt with eating and teeth both pre and post survey is likely also rooted in the fact that the experiment itself focused on feeding and food conversion. Thus, although the goal was for students to revise their view of sharks from stereotypical "eating machines" to a more holistic view of sharks, this effort was confounded by involving the students with a feeding experiment.

Smaller Changes in Students' Attitudes Toward Scientists

Despite the strong partnership between the scientist, the K–12 teacher, and the students, improvement in students' attitudes about scientists was not clearly evident. Students did reduce their negative word choice associated with scientists, but their overall impression of scientists was fairly positive to begin with, and students also used many words associated with scientific process, both of which were implicit goals of the partnership. However, upon examination of the actual words chosen by students, much of their positive visions of scientists indicated a disconnection between themselves and scientists (e.g., special, unique, brave, etc.). This concern is reinforced by studies looking at the glamorization of scientists in television shows such as CSI (see Deutsch, 2006; Duncan & Daly-Engel, 2006; Willing, 2005). In addition, although the number of responses in the scientific method category is an overall positive finding concerning student's attitudes about science, the composition of words dealt mostly with rote process (e.g., experiment, study, tests, research). Responses dealing with scientific thought and habits of mind (e.g., curious, thinking, observation) were much less frequent, even in post-evaluations. This is possibly due to the predetermined nature of the shark experiment protocol. Even though students participated in aspects of the research design and data analysis, the inquiry was not completely open ended.

Furthermore, as has been repeatedly demonstrated (see Chambers, 1983; Mead & Metraux, 1958; Thomas & Hairston, 2003), students' views of scientists in this study were closely linked to equipment (e.g., labs, lab coats, chemicals, goggles). In fact, almost 25% of scientist words dealt with equipment, both pre and post survey, even though the materials listed by students were generally not those used in the partnership research (with the exception of scales). This association of scientists with specialized and even unfamiliar equipment rather than an association with a human thinking process is fundamental to the difficulty in helping students to become scientifically literate and take ownership of their ability and obligation to effectively evaluate scientific information encountered in their daily lives.

An additional explanation for the lack of change in students' attitudes about scientists is that scientific demeanors and habits of mind were an integrated part of the partnership rather than an overt content topic addressed during the lessons. In contrast to the shark education portion of the project where students were exposed to a variety of sharks and spent a great deal of time investigating and discussing shark biology, there was not a formal emphasis placed on the diversity of scientists or the variety of methods used to do science. Rather, it was assumed that the students would see that the participating scientist was young, female, and active (rather than the stereotypic student view of a frail, elderly male) and that this would help students better relate to this scientist in particular and science in general. Such relationships have demonstrated positive attitude shifts in previous research (see Flick 1990; Smith & Erb, 1986 who describe increased representation of female scientists in student drawings after exposure to female university scientists and graduate students). However, in this study, post-survey student responses suggest that the scientist was still not seen as "one of them"—perhaps because of differences in ethnicity between the white scientist and the majority of students who were nonwhites. This suggests that to help students identify themselves as scientists, targeted activities, discussions, and follow-up are needed on a level comparable to effort directed at other curricular concepts and skills. For the advancement of scientific literacy and science education practice, it is recommended that future research investigate how to effectively engage and reconstruct students' beliefs about scientists and strategies for incorporating such methods into partnerships and project-based learning.

Support for the Use of First-Impression Words in Attitude Assessment

The use of words to assess students' attitudes appears to be a useful method and provides an alternative to drawing tests. The use of words allowed students to relatively quickly express a variety of ideas and emotions and allowed collection of data on a topic (sharks) for which there was not a preexisting system for scoring. Although validity threats for the first-impression word method include the use of the availability heuristic (i.e., making judgments based on information that is easily brought to mind) and the presence of the stability bias (i.e., assuming that recent behaviors are typical of all behaviors), the availability of student comments helped to validate the nature of students' attitude shifts (i.e., students wrote that the experience had changed their view of sharks). In future studies, it would be beneficial to solicit student opinions about the themes used to categorize words into themes. It would also be instructive to couple the word data with questions that directly ask students to rate their attitudes pre and post partnership.

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Keywords: Project-based learning; GK–12; social cognitive theory; behavior.

Appendix. Grid of Concepts and Associated Questions Posed to Students in the Lesson Series. ljjessons are Aligned to the National Science Education Standards. (National Research Council, 1996) 6

Concept	Question	Lesson	National Science Standards
Shark biology	What makes a shark a shark?	Students create a bony fish & a shark drawing on the blackboard by taking turns adding one body part at a time.	Biological evolution
		Discuss general fish anatomy showing differing forms between bony & cartilaginous fish on blackboard drawings.	
	What senses do sharks have & how sensitive are they?	Use the blackboard drawing to talk about senses that sharks & fish have.	Behavior of organisms
		Shark senses distance game: points are marked on a string corresponding to shark senses. Students then match picture cards of shark senses to distance of sensibility.	Abilities necessary to do scientific inquiry
		Shark smell dilution experiment: students dilute lemon juice (urine) & tomato juice (blood) in parts per million to compare the point where human senses & shark senses stop detecting the two solutes.	Structure & properties of matter
	What do Sharks eat?	Matching: nine types of sharks are represented by a photo of their teeth, prey, & body. Students match pictures.	Behavior of organisms
		Introduce sharks as picky eaters, differing in diet from species to species. Use examples from matching game.	Biological evolution
		Food is energy. Discuss how much food a shark needs to survive.	Matter, energy & organization in living systems
Trophic levels & energy transfer	Where do sharks fit in the marine food web?	Who am I? Students ask yes/no questions of classmates to determine their marine organism (taped to their back) & then build a food web with string between classmates to investigate the interdependence of marine organisms on each other.	Abilities necessary to do scientific inquiry Interdependence of organisms
	How is energy transferred between organisms?	Discussion of trophic levels & energy transfer	Conservation of energy & increase in disorder
		M&M energy transfer game. One student is the shark & is at the top of the “food chain”. M&Ms begin at the sun & are transferred from phytoplankton through various marine organisms, decreasing in number with each transfer.	Interactions of energy & matter Interdependence of organisms
Experiment design	How do you design an experiment?	Mind map of where food goes upon entering a shark’s body.	Matter, energy & organization in living systems
		Develop mock experiment & methods needed to investigate a question about sharks & food.	Understandings about scientific inquiry
	How do we conduct a feeding experiment on live, juvenile hammerhead sharks?	Students help brainstorm & design hypotheses & methods for this scientific study on hammerhead shark gross conversion efficiency.	Nature of scientific knowledge Behavior of organisms
		Schedule for how we will accomplish our methods, including issues of animal health & environmental quality throughout experiment.	Environmental quality
		Logistics for students coming to participate in the optional field portion with live sharks.	Science as a human endeavor

Appendix, Continued

Concept	Question	Lesson	National Science Standards
Diversity of form & function	How do you know what kind of shark, skate or ray it is? And, how are they different?	Students discuss basic form & function of sharks, skates & rays.	Biological evolution
		Power point presentation on the diversity of sharks. Students observe differing color, shapes, & sizes between species, & they discuss potential adaptive advantages.	Behavior of organisms
		Shark ID: Students distinguish between different species of local sharks on a power point presentation using photo guides.	Nature of scientific knowledge
	What is your favorite elasmobranch really like and how does it survive?	Each student chooses a species of elasmobranch to research & present about.	Abilities necessary to do scientific inquiry
		Clay Shark: Students sculpt & paint a clay shark to be part of their presentation. Designed to reinforce the concept that there is variety and specificity in elasmobranch form.	Biological evolution Science as a human endeavor
		Cartoon: Students are given sample shark cartoons. As part of their research presentation, each student makes a cartoon about their chosen species or of scientists trying to understand it.	Nature of scientific knowledge
Combining cultural legends, research & personal data	How do people feel about sharks & what do we really know?	Power Point presentation on shark history & public views of sharks.	Historical perspectives
		Information about shark attacks	Nature of scientific knowledge
		Results of tiger shark research conducted by scientists at the University of Hawaii.	Science & technology in local, national & global challenges
	What did we learn in our feeding experiment with hammerhead sharks?	Review of experimental results. Students graph results, compare to hypotheses & to other classes results.	Understanding about scientific inquiry
		Class discussion of results, conclusions & implementation of the experiment.	Science as a human endeavor
		Students present their independent research elasmobranchs (clay models & cartoons) to the class.	Nature of scientific knowledge

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