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The 'Adopt-A-Microbe' Project: Web-based Interactive Microbiology Education Connected with Scientific Ocean Drilling

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Marine scientists have unique opportunities to interact with educators and learners during voyages at sea to encourage engagement in cutting-edge science and understanding of the scientific process. Real-time, ship-to-shore education and outreach activities are increasingly common during oceanographic expeditions as a mechanism to connect broader communities to oceanographic research. In this article, we report on the 'Adopt-A-Microbe' project (AAM), a program of education and outreach designed and run by scientists, education specialists, and artists working together during an eight-week oceanographic expedition. This unique educational program combined science and art to encourage learning about life at the bottom of the ocean. The AAM target audience was primary and lower-level secondary school students, but we also hoped to attract and maintain engagement with parents, older siblings, teachers, and others interested in ocean exploration. We describe the architecture of AAM as a template for other scientists and educators to use and build upon, highlighting hands-on activities and art projects that were part of the curriculum that could be integrated into other classroom activities.

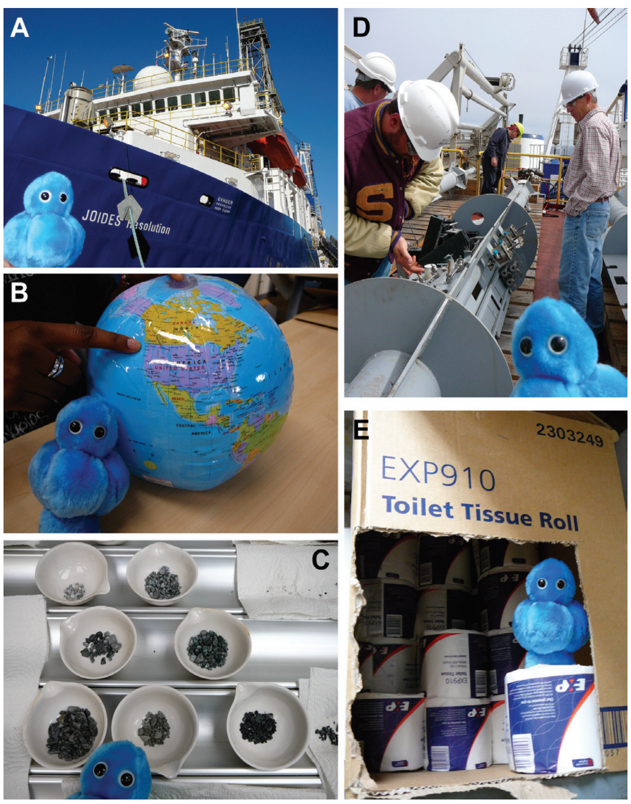

Figure 1A-E. Examples of the fictional microbe character SAM used on the Adopt-A-Microbe website. (A) SAM in front of the research vessel *JOIDES Resolution*; (B) SAM with a globe marking where the scientists were conducting research; (C) SAM posing with rock samples collected during scientific ocean drilling; (D) SAM in front of scientific equipment that was deployed at the bottom of the ocean; and (E) SAM in a box of toilet paper, which accompanied the Week 4 math problem set.

PROJECT OVERVIEW

The general concept of the inaugural AAM project (https://sites.google.com/site/adoptamicrobe) was to use virtually 'adopted' and fictional character microbes as focal points for a web-based, interactive science education experience (Figure 1). The project was launched in association with Integrated Ocean Drilling Program Expedition 327, and later versions of the project built from this framework with modifications as appropriate. Participants in the inaugural AAM project learned about marine microbiology, scientific ocean drilling, and the scientific process through weekly hands-on activities centered around their adopted microbes (Figure 2 on page 42), and from text and multimedia updates on the website. Artistic elements—such as watercolor illustrations accompanying fictional stories written from the perspective of microbes (Figure 3 on page 43), and hands-on activities with photography, poetry, and model making—were included alongside more traditional scientific activities to encourage creative learning.

The central portal of the education experience was the project website, which had three main components: (1) an 'Adoption Center' with information about the microbes up for adoption; (2) a blog for discussion and presentation of weekly activities; and (3) the main informational blog focused on scientific topics related to the expedition. Candidate microbes for adoption were identified based on their relationship to the bottom of the ocean and other unique characteristics (Table 1 on page 41). Background material about the microbes was gathered from sources such as the 'MicrobeWiki' (microbewiki.kenyon.edu), and from more traditional textbooks and peer-reviewed scientific journal papers. Brief, easy-to-understand informational sections were created for each microbe for posting at the Adoption Center. Weekly activities were developed to use the adopted microbes as focal points for increasingly complex learning exercises about microbiology. The informational blog was called the 'Giant Microbe Update,' making reference to a plush microbe toy used as the narrator for many of the posts (Figure 1 on page 40). This blog used a combination of artistic illustrations, videos, storytelling, and photographs to convey information. Participants in the project followed along with the blog posts to receive new information and activity instructions, to have opportunities to send questions and comments to the scientists at sea, and to see the results of other participants' activities posted alongside their own.

HANDS-ON WEEKLY ACTIVITIES

Eight weekly activities were offered as part of the AAM project. For specific details about each activity with step-by-step activity instructions and safety precautions, please see the project website (https://sites.google.com/site/adoptamicrobe or http://darkenergybiosphere.org). Weekly activity instructions were posted on Mondays, and the participant projects were posted on the website on Fridays. Please note that the fifth and eighth activities listed on the website, which involved culturing common microbes, are somewhat advanced for the age range that was the primary target for the AAM project. Although these activities can be completed safely under the supervision of an adult, microbial culturing is not consistent with safety guidelines for middle school classrooms developed by the National Science Teacher Association (NSTA).

In the first activity, project participants were asked to submit questions about their adopted microbe, based on information provided on the project website or through other sources. This activity exposed project participants to information about microbial morphologies, habitats, survival strategies, and other characteristics. Example questions that were submitted about *Marinobacter aquaeolei* included "how is oxidizing iron important to the global carbon cycle?" and "would these bacteria help with cleaning up the spill from the Deepwater Horizon?" At the end of the week, participants were provided with non-technical answers to all of the questions posted on the website.

In the second activity, the participants constructed models of their adopted microbes using balloons. Participants were encouraged to embellish their balloon models with features that were representative of microbial lifestyles, enhancing visual learning. Participants submitted pictures of their balloon model microbes, which were posted on the website, allowing others to view and comment on these artistic constructions. Figure 2A on page 42 shows an example of one of the submitted projects.

The third activity had the participants write haiku (three lines of poetry containing five, seven, and five syllables each) about some facet of their adopted microbe. By limiting the activity to haiku format, the project participants had to distill their learning about their microbe into short phrases. Such a format was chosen to enhance later, post-project recall of the activity (e.g., reciting the haiku), as well as to expose project participants to an international form of poetry, which ties into the multicultural nature of oceanographic science. Many of the submitted haiku were direct, factually correct, and nuanced, like these:

What is a microbe?
Oldest form of life on Earth
Single celled creature

My home is boiling
I produce a gas–methane
I look like a stick

Species Name	Association to Dark Ocean
Alcanivorax borkumensis	Isolated from marine sediments, able to degrade hydrocarbons found in oil
Archaeoglobus fulgidus	Found in marine hydrothermal vents and oil wells
Arcobacter sulfidicus	Found in marine hydrothermal vents
Beggiatoa spp.	Found in sulfidic marine sediments
Desulforudis audaxviator	Found in the terrestrial deep biosphere (South African gold mine)
Desulfovibrio desulfuricans	Found in sulfidic marine sediments
Marinobacter aquaeolei	Found in deep ocean water and oil wells
Mariprofundus ferrooxydans	Isolated from hydrothermal vents on Loihi Seamount
Methanocaldococcus jannaschii	Found in marine hydrothermal vents
Methanopyrus kandleri	Found in marine hydrothermal vents
Photobacterium profundum	Isolated from marine Japan Sea sediments, able to grow at high pressures
Shewanella loihica	Isolated from Loihi Seamount
Thiomargarita namibiensis	Isolated from marine sediments

Table 1. List of 'microbes' that were available for virtual adoption, with information about why each microbe was relevant to the objective of increasing knowledge about microbes in the deep dark ocean.

In the fourth weekly activity, participants were asked to work through some short mathematical calculations related to microbial research. After reading background information relevant to the scientific expedition, participants were asked to calculate: how many microbes live in the ocean, how long it takes to work with scientific core samples, and the quantity of supplies needed for successful scientific research? At the end of the week, answers to the problems were posted on the website along with discussion of the implications of these calculations.

In the fifth activity, participants made associations between microbes living on teeth and microbes living on rocks by inoculating growth media plates with oral swabs. For the activity, participants were encouraged to collect swabs of different samples (oral samples before and after toothbrushing and other similar surfaces) and then report on the development of microbial colonies on growth media plates. This project provided a hands-on experience with microbiology research techniques and opportunities for hypothesis testing (e.g., do more colonies develop on samples collected before or after toothbrushing?). At the end of the week, participants submitted pictures of the results of their growth experiments, which were posted on the website along with additional information about culturing and studying marine and subseafloor microbes (an example is shown in Figure 2B).

Like the second activity, the sixth activity encouraged tactile and creative methods for learning about microbiology, this time through the construction of stuffed fabric 'giant microbe' models. Project participants were provided with patterns and instructions for creating spherical and/or kidney-shaped fabric microbes, and were asked to submit pictures of their fabric microbes for posting on the website (an example is shown in Figure 2C).

Figure 2A-D. Here are samples of the Adopt-A-Microbe weekly activity participant projects. (A) Week two balloon model microbes of *Alcanivorax borkumensis,* oil-eating bacteria; (B) Week five tooth swab culture project; (C) Week six fabric microbes; and (D) Week seven project to collect gas produced from yeast.

The seventh activity was the last one of the AAM project to follow the typical timeline of posting the activity at the beginning of the week followed by a re-cap of the projects at the end of the week. In this activity, participants conducted another hands-on microbiology experiment to learn about gas production by microbes, affectionately referred to as 'microbe farts.' Project participants grew common baker's yeast (as a proxy for microbes) and captured the gas produced during incubation in balloons (as shown in Figure 2D). As another opportunity for hypothesis development and testing, suggestions were provided for growing the yeast on different substrates. Through this experiment, the participants learned how microbes make gas while growing, which is an important component of microbiology in the marine subsurface, and about how scientists study microbial activity in the environment using proxies to measure metabolic activity.

The final activity of the AAM project was an open-ended experiment to expose project participants to microbes living in the environment. The project was centered on the construction of a 'Winogradsky column' (Anderson and Hairston 1999)—so named after a late-19th-century scientist studying microbes living in soils and freshwater sediments. In the experiment, project participants were encouraged to collect samples near their homes of freshwater sediment from a water body, mix the sediment with food sources for the microbes (i.e., hard-boiled egg yolk as a sulfur source and shredded newspaper as a carbon source), and leave the sediment mixture in a vessel for a few weeks to allow the sediment microbes to become enriched. (This activity required three to six weeks of time for the enriched microbes to develop, so the course was extended beyond the end of the main oceanographic expedition.) This activity encouraged hands-on environmental science learning and continued exploration of topics related to microbial communities and function.

USING ART FOR SCIENCE COMMUNICATION

In addition to using art projects in weekly activities to engage scientific learning, artistic elements such as painting, storytelling, and videos were prominent in other parts of the AAM project. A regular feature of the 'Giant Microbe Update' blog consisted of updates from a fictional microbe character narrator (Figure 1 on page 40). The use of a toy microbe as a narrator added a fun and unique element to the information for engaging the audience, established a consistent "character" through the updates, and helped the project participants view the research being conducted from the perspective of a microbe. The microbe was named 'SAM,' for Super Awesome Microbe, based on a naming contest offered through the blog. SAM was featured in photographs taken around the research vessel to anchor the information being presented. In addition, SAM was used as the introductory narrator for subsequent blog posts given from the perspective of other guest microbe characters.

The fictional stories and illustrated artwork created from the perspective of microbes living at the bottom of the ocean were also a central artistic component of the AAM project

Figure 3. Watercolor illustration of marine deep subsurface microbes that accompanied fictional stories from the *DEBI*.

(Figure 3). The purpose of this feature was to expose the project audience to interesting aspects of microbial life below the seafloor through storytelling (for instance: what it might look like, what the microbes are doing, how conditions after drilling might be different than conditions before drilling). The stories were written by scientists, and the artwork was created by the shipboard artist. The first storytelling series revolved around a character named 'DEBI,' named after the Dark Energy Biosphere Institute that supports microbial research at the bottom of the ocean (darkenergybiosphere.org). Over a five-week period, five new stories and illustrations from DEBI were posted at the AAM website. The narrative of these stories followed DEBI in 'her' description of life in 'Subsurficia' with other microbes, the encounter of DEBI with the drill bit used by scientists to collect samples, and the colonization by DEBI and her microbe friends into the new colonization devices placed in the subseafloor observatories.

The second series featured a character named 'Mario the Marinobacter.' This series told the story of a surface seawater microbe that gets a chance to travel below the seafloor into the ocean crust and then return to the surface ocean. During 'his' adventures in this new environment, Mario highlights some of the differences and similarities between microbial life in sunlit sea water and life inhabiting dark cracks and pore spaces within the ocean crust.

Custom-made 'Giant Microbe Videos' of two to fifteen minutes in length illustrating different activities occurring onboard the research vessel were also used to link artistic and scientific communication. To add an element of creativity to the sometimes technical and repetitive nature of the material presented, video footage was often increased in speed (up to eight times normal) to show the video subjects moving very rapidly (and somewhat comically). The videos also helped show the extensive amount of work and people required to complete multidisciplinary oceanographic research. Videos also featured interviews with scientists and other shipboard personnel, as well as "pop-up" text banners to explain the visualized activities.

LESSONS FROM THE FIRST 'ADOPT A MICROBE' PROJECT

For scientists and educators interested in developing a similar educational program, or in participating in a future AAM project, we offer the following advice based on our experiences. In brief, we make recommendations concerning ways to increase participation in the project, the utility of connecting hands-on activities with real-world events, and the importance of advance planning.

Quantitative metrics suggest that the project was successful in reaching target audiences and helping to encourage and maintain interest in topics related to scientific ocean drilling. A website tracker (set up through Google Analytics) allowed assessment of the number of visitors to the site over time, with corresponding statistics on the length of time visitors spent on the site and the geographical location of those visitors. Overall, there were >1,500 visits to the project website during the eight-week expedition. The majority of website visitors originated from the United States, with Canada, western European countries, Australia, India, and Japan also contributing a fair number of visitors. On average, visitors to the site spent about 2:36 minutes on the website and viewed 2.7 pages per visit. Many visitors to the site were directed there from referral websites such as Facebook (24% of visits) or the main page of the *JOIDES Resolution* outreach program (15%), while 34% of visits to the site were direct, most likely from links to direct pages from email notifications sent to project participants.

Engagement could also be assessed by the number of projects submitted by participants for each week's activity. A total of 25 individuals or groups officially registered to be participants in the AAM project. Of those, about half regularly submitted weekly activities near the beginning of the project, and participation dropped to 2-3 submitted activities by the end of the project. The decrease in participation coincided with the start of a new school year in many parts of the U.S., an unavoidable conflict in timing that diverted attention of the participants away from the project. Oceanographic expeditions are scheduled based on technical logistics and not around school calendars, but future projects can coordinate with school schedules to encourage more regular participation. Similarly, early engagement of science camps, clubs, and museum groups may also ensure more regular participation.

Participant feedback was provided both through direct solicitation (by asking participants to take a survey about the project) and unsolicited comments provided by participants to the project leaders. The survey was created using a free online program (www.surveymonkey.com). Voluntarily offered information from some of the active project participants indicated that the majority were 14 years of age or younger or older than 65. Most of them found out about the project through an email solicitation from a network, friend or colleague, or by mention on a social network or organizational page. These statistics should be viewed with caution however, as they represent a small sample size (n=6 survey responders).

Trends in microbe 'adoption' during this AAM project highlighted the importance of hands-on association of science concepts with real-world events. For example, of the 13 microbes offered for adoption, a few were adopted more frequently than others. *Alcanivorax borkumensis,* a marine microbe that is able to degrade oil and hydrocarbons, was a popular adoptee, likely owing to the timely association of the AAM project with the *Deepwater Horizon* oil disaster in the Gulf of Mexico. This overlap offered an opportunity for associating real-world events that the general public was interested in with scientific education.

Overall, the inaugural edition of the 'Adopt-A-Microbe' ship-to-shore education and outreach project engaged students across a spectrum of ages and experiences in science education associated with a complex oceanographic expedition. Weekly hands-on activities offered in a virtual forum, combined with information provided through non-conventional means (i.e., storytelling by a fictional microbe characters), exposed project participants to a range of STEM (science, technology, engineering, and mathematics) topics, including microbiology, environmental science, geology, oceanography, and engineering. Cumulatively, the project incorporated "5E" learning cycle elements: engaging students in ocean science with characters, art, and storytelling; encouraging students to explore new information about life at the bottom of the ocean through hands-on activities; asking students to explain their understanding by submitting projects; helping students to extend their knowledge by making comparisons to observations from daily life and developing new hypotheses; and providing feedback and evaluation to participants' projects.

While the project described in this report was completed in 2010, modified versions of the program have occurred and are planned for other scientific expeditions (visit darkenergybiosphere.org for more information); thus, there will be opportunities for future participation. Based on the feedback from educators, future projects will incorporate more simulations and hands-on activities that are "tied-in" with established curricular goals and assessment rubrics developed for a more quantitative evaluation of program success. One new activity may involve the evaluation of different rocks from the bottom of the ocean, and an analysis of rock reactivity when exposed to acidic conditions (similar to experiments described for studying ocean acidification; Bruno et al. 2011). We hope the program continues to evolve, and we welcome feedback and involvement from educators.

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REFERENCES

Anderson, D.C., and R.V. Hairston. (1999). The Winogradsky column and biofilms: Models for teaching nutrient cycling and succession in an ecosystem. *The American Biology Teacher* 61(6): 453-459.

Bruno, B.C., K.A. Tice, N. Puniwai, and K. Achilles. (2011). Ocean acidification: Hands-on experiments to explore the causes and consequences. *Science Scope* 34(6): 23-30.

Whitman, W.B., D.C. Coleman, and W.J. Wiebe. (1998). Prokaryotes: The unseen majority. *Proc. Nat. Acad. Sci. USA* 95:6578-6583.

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