

BEYOND THE EDGE OF THE SEA:
EDUCATIONAL PROGRAMMING FOR A MARINE SCIENCE ART EXHIBIT
GRADES K-12

by
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Abstract

The ocean is the largest biosphere on earth covering about 70% of the earth's surface. Yet, very little is known about this deep sea environment due to its inaccessibility. The task of educating the public about deep ocean environments and making people care about them is no easy job. One team made up of a hydrothermal vent scientist and a watercolor artist have come together in a collaborative effort that will convey the beauty, awareness and understanding of the deep sea. The format for displaying information will be a traveling art exhibit that showcases illustrations of deep sea environments and the communities that live there.

The specific objective of my master's project was to produce museum programming for Grades K-12 to accompany the exhibit, in order to promote ocean education and awareness of chemosynthetic communities. Upon completion the lesson plans will be posted on the Muscarelle Museum of Art web site, providing educators access to educational materials before arrival at the exhibit. The published activities will be correlated to the National Science standards published by the National Research Council and Ocean Literacy standards.

The anticipated response is for students to be inspired by and aware of the deep-sea and the amazing life that is found there. By recognizing the existence of deep sea organisms, individuals may become stewards for them and their environment. Each set of activities follow a standard lesson plan format and include: background information, materials, standards, materials and procedures. In addition, all lessons follow the interactive museum experience model, a guide for developing education programs in settings like museums.

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Introduction

Beyond the Edge of the Sea is a marine science art exhibit that aims to educate the public on the existence, importance, and significance of the deep sea. The illustrations in the exhibit are the result of a fifteen-year collaboration between Cindy Van Dover, a deep sea biologist and hydrothermal vent expert, and watercolor illustrator Karen Jacobsen. The two women decided to bring their unique talents together to educate others about the existence of extreme deep ocean environments.

The objective of *Beyond the Edge of the Sea*, as stated in the project description, is to develop an outreach program to improve the general public's understanding of science and technology. This will be accomplished through a traveling exhibition of illustrations of organisms that live at deep-sea hydrothermal vents, with accompanying educational elements. I worked in conjunction with the North Carolina Maritime Museum and one other Duke Marine Lab graduate student to develop educational materials for Grades K-12. The educational materials designed for Grades K-2, 3-5, and 6-8 can be found in Appendices A through C. The plans for Grades 9-12 are not included in this document; however they will be included in the material packet that will be available to teachers.

Background/Purpose

According to the 2000 US census, 137.5 million people live within a 50-mile zone of the coastline. This constitutes close to 50 % of the US population. Most of these individuals do not have an awareness or appreciation of the deep-sea environment and the fauna found there. In 2003, the Pew Oceans Commission published *America's Living Oceans: Charting a Course for Change*, which calls for broader "ocean education and awareness through

a commitment to teach and learn about our oceans at all levels "(Pew Oceans Commission 2003). The following year, the U.S. Commission on Ocean Policy published its own report recommending the need to the for greater ocean stewardship (USCOP 2004). A person can not be a steward of the environment, let alone the ocean, if they do not know it exists.

Beyond the Edge of the Sea visitors should leave the exhibit with an awareness of the deep sea and general knowledge of the organisms found there. This artistic forum can act to bridge the gap between the scientific community and the general public. Visitors will gain an appreciation of the deep sea and will be motivated to learn more and tell others about the existence of hydrothermal vents, cold seeps, and whale falls. Communicating scientific information through art can also emphasize the importance of scientific documentation and lead individuals to place value on future ocean explorations.

Interest in ocean exploration can lead to significant discoveries. In 1977 the first hydrothermal vents and their associated chemosynthetic communities were discovered at the Galapagos Rift off of the coast of Ecuador. This discovery altered the way scientists thought about life on earth. Until this discovery it was believed that any organism living on the sea floor was dependent on the food chain that originated with sunlight and photosynthesis as well as organic material sinking to the bottom of the ocean. However, at hydrothermal vents approximately 2,500 meters below the oceans surface, scientists found large communities of organisms made up of tube worms, mussel, clams, crabs and shrimp. These organisms get their energy not from the sun but from bacteria that convert vent chemicals into energy by a process known as chemosynthesis. This discovery changed what scientists believed was needed for life. The implication that life can exist without sunlight challenges us to think about our world differently and may lead us to other exciting discoveries.

Environmental Education and Ocean Literacy

Environmental education can trace its roots back to 1905 when L.H. Bailey, a teacher who focused on nature in his classroom, first came up with the term. It was not until the 1970s that education in favor of the environment came to fruition (Marsden 1997). In 1976, with the United Nations adoption of the Belgrade Charter at the International Environmental Workshop held in Belgrade, Yugoslavia, a global framework to address environmental issues was established. This document instituted the goal of environmental education stating

environmental education is to develop a world population that is aware of, and concerned about, the environment and its associated problems, and which has the knowledge, skills, attitudes, motivations, and commitment to work individually and collectively toward solutions of current problems and the prevention of new ones (UNESCO-UNEP 1976).

A year later in Tbilisi, Georgia (USSR), the World's first intergovernmental conference on environmental education assembled. This conference was a collaborative effort between delegates from 66 member states, nongovernmental organizations, intergovernmental organizations, other U.N. agencies and observers from nonmember states. A total of 330 people attended the conference. At the conclusion of the conference, the Tbilisi Declaration was unanimously passed. This declaration built on the goal of environmental education as stated in the Belgrade Charter and assigned the role, objectives, and characteristics of environmental education. Today there are many organizations functioning under the framework of environmental education; they are all working towards providing the public with knowledge, skills, and positive environmental experiences so that they can make informed decisions about the environment and take responsible actions (NAAEE 2004). The overall goal is to provide a foundation for environmental education and the creation of an environmentally literate citizenry (EETAP 1997). According to the

Environmental Education and Training Partnership, environmental education should be taught in both formal and non formal education settings that foster an atmosphere of awareness and ethics that will result in an environmentally literate society.

Similar to the ideals of environmental education is the concept of Ocean Literacy. Recommendations made by both the Pew Ocean Commission and the U.S. Commission on Ocean Policy have called for a greater emphasis of ocean issues and stewardship within the classroom. The US Commission on Ocean Policy states "School curricula, starting in kindergarten, should expose students to ocean issues, preparing the next generation of ocean scientists, managers, educators, and leaders through diverse educational opportunities (USCOP 2004). The principles behind Ocean Literacy were developed by scientists, science educators, informal educators, and parents in collaboration with Centers for Ocean Sciences Education Excellence Network, National Marine Educators Association, National Geographic Society, National Oceanic and Atmospheric Administration, Sea Grant and others. Their collaboration began in the fall of 2004 with a series of online workshops. The purpose of these workshops was to develop content standards related to the marine environment including the ocean, coastal zones, and Great Lakes. The expectation was that establishment of these standards would further the representation of ocean content within state and national science education standards. Participation in the workshop by education professionals including teachers, administrators, parents, and informal educators aimed to stimulate the future development of ocean content and its integration into science standards.

The Ocean Literacy Workshop developed the concept that "Ocean literacy is understanding the ocean's influence on you and your influence on the ocean" (Ocean Literacy Network 2005). Consequently, an ocean-literate person understands major concepts about how the ocean operates, can convey to others the significance of the ocean,

and is able to make educated and conscientious decisions concerning the ocean and its assets. Ocean Literacy is based on seven essential principles each further detailed by fundamental concepts. These essential principles are as follows:

1. Earth has one big ocean with many features.
2. The ocean and life in the ocean shape the features of Earth.
3. The ocean is a major influence on weather and climate.
4. The ocean makes Earth habitable.
5. The ocean supports a great diversity of life and ecosystems.
6. The ocean and humans are inextricably linked.
7. The ocean is largely unexplored (Ocean Literacy Network 2005).

Currently, ocean sciences are underrepresented in schools. These principles were created in order to increase awareness of ocean issues. The challenge has been to identify key ocean concepts that can be easily incorporated and aligned with the National Science Education Standards. Eventually, these guidelines should be integrated with the core curriculum education standards of individual states.

In the future, the Ocean Literacy Network wants to expand their reaches and develop specific lessons and activities that teachers can use in the classroom. These lessons will not only cover ocean content but will integrate ocean science with other subject areas in order to address the core content area standards within other fields of study. Professional development modules will also be crafted to enlighten and excite educators about ocean science and inspire them to teach it in their classrooms. Additionally, research will be conducted that will confirm the positive influence of ocean content on other subject matter.

The intention of *Beyond the Edge of the Sea* is to serve as a public outreach program. Its goals align closely to those of environmental education and Ocean Literacy. As with environmental education, this exhibit raises awareness, and specifically, awareness of the deep sea. By using art illustrations as the format to educate the public, individuals will be inspired on a level that encourages them to make responsible decisions regarding the

wellbeing of the ocean. The seven essential principles outlined by the Ocean Literacy Network relate to this exhibit as well. They were used as an inspiration for the development of the educational materials. All lessons are correlated to these principles.

Connecting Science and Art

At first, connections between science and art may not be clear, but the two subjects share a common purpose. Art is emotional, visual, and seeks an aesthetic reaction, while science is based more in reason, explanations, and knowledge. However, both art and science attempt to make sense of the world around us and communicate our knowledge, experiences, perceptions, and ideas both art and science have the potential to enrich our lives (Siler 2004). Other similarities between art and science include:

- Valuing the careful observation of their environments to gather information through the senses.
- Valuing creativity.
- Proposing to introduce change, innovation, or improvement over what exists.
- Using abstract models to understand the world.
- Aspiring to create works that have universal relevance (Wilson, 2002).

One of the goals of this exhibit is to establish an environmentally literate citizenry. Establishing a connection between the surrounding world and the individual is essential to achieving this goal. Art can act as that link, inspiring and providing an emotional bond to an environment like the deep sea. Awareness of the ocean is a major goal of ocean literacy, and using the personal context one gains from art can motivate individuals to learn more about and value the marine environment.

Show-casing the beauty of the deep sea through art is a way for the public to be exposed to the inaccessible reaches of ocean. Providing illustrations through the exhibit *Beyond the Edge of the Sea* provides the link that is missing. Dr. Cindy Van Dover, the director of the Duke Marine Lab, expert on hydrothermal vent communities, and curator of this exhibit states “If we omit this style of observation and documentation from our scientific agenda, we have lost part of our heart; we are poorer for it.” The artist’s feeling and experiences with the environment come out in her work and act to inspire as she shares her understanding with of natural world.

This is not the first time that scientists and artists have worked together. Within the Duke University community a notable example is the collaboration between Orrin Pilkey, James B. Duke Professor Emeritus of Geology at Duke, and textile artist Mary Edna Fraser who together produced the exhibit *Expanding Oceans*. Fraser saw her role in this partnership very distinctly, saying she “would be a visual voice for his scientific mind” (Pilkey and Fraser 2003). Their exhibit used art to share scientific ideas about global climate change, combining both factual information and emotional responses. Arts editor Mary Wade said about the exhibit “The pieces drew me in from a distance with their aesthetic presence, but the messages by each work made me stop and reflect.....” (Wade 2008). It is clear that presenting environmental information in an artistic format succeeds in educating and inspiring the public.

Art like Karen Jacobsen’s sketches and watercolor illustrations of the deep sea are used to communicate science for a multitude of reasons. Illustrations can help bring attention to what a scientist is saying out loud or on the written page. Illustrations can help scientists effectively share information with other scientists. Illustrations can be used to persuade organizations to fund scientific research. Illustrations can convey the importance

of scientific work to the public and be used to assist in teaching students (Briscoe 1996). In essence, “drawing can communicate faster and more dynamically than words. It can clarify, simplify, and emphasize information in an interesting and inspiring way. Drawings are a priceless help in communicating information” (Briscoe 1996).

As far back as to 16th century, illustrations have been an important form of scientific communication. When specimens were too delicate to be shipped between naturalists, scientists would sketch organisms as a way to communicate the appearances and characteristics of samples to each other (Pyle 2000). One naturalist, Conrad Gessner, especially realized the importance of drawing and written observations. His drawings demonstrate an understating of the importance of detail as a way to educate, know and understand (Pyle 2000).

Educational Settings

Learning happens in both formal and informal settings. Formal education is based inside of the classroom where teachers are restricted to teach core curriculum content standards. On the other hand, informal education is any place that learning occurs outside of the classroom, including, but not limited to, museums, libraries, after-school programs, and community based programming.

The museum programming developed for this exhibit will be a combination of both informal and formal learning experiences. Educators will have access to lesson plans online before groups visit the art exhibit. There are three individual lesson plans per grade level. The first lesson is intended as an introduction, the second lesson is an activity to complete while in the exhibit and the final lesson acts to bring home key points. The pre- and post-lessons are available to teachers prior to their visit and are intended for the classroom setting

and therefore follow a more structured format. Activities created for time spent in the museum are less structured and are based on an informal education model.

Though it seems straightforward at first, there is much debate over the nature and context of learning. In fact, the boundaries between formal and informal education are difficult to classify. In a review of the literature, Colley, Hodkinson, and Malcom conclude that “it is difficult to make a clear distinction between formal and informal learning as there is often a crossover between the two” (Colley *et al.* 2002). Formal education is education that takes place in classroom settings with set objectives. Informal education does not have a clearly defined definition, rather it is spoken about in terms of what it is not. It is not formal; it is not structured. It is learning “that happens away from classrooms, schools, and educational institutions” (Vavoula 2005). Stern and Sommerlad see formal and informal education as being on a continuum that can never be fully separated into categories (Stern and Sommerlad 1999). This continuum runs from deliberate learning with the intention of certification to the other end of the spectrum where learning is purely accidental (Figure 1).

According to Colley *et al.*, formal and informal education are not mutually exclusive:

it is not possible to separate out informal (...) learning from formal learning in ways that have broad applicability or agreement. Seeing informal and formal learning as fundamentally separate results in stereotyping and a tendency for the advocates of one to see only the weaknesses of the other. It is more sensible to see attributes of informality and formality as present in all learning situations. These attributes are characteristics of learning to which writers commonly attach labels such as formal and informal. The challenge is to identify such attributes, and understand the implications of the interrelationships between them. For analytical purposes, it may be useful to group these attributes into four aspects of learning. They are: location/setting, process, purposes, and content (Colley *et al.* 2003).

Other authors claim that there is no such thing as informal education, while still others believe that not only is there informal education, there is also non-formal education, which is intentional learning by the individual that occurs in a outside of a formal educational

institution. However, many times informal and non-formal learning are used interchangeably with no clear difference in terms. According to Falk and Dierking, this debate is irrelevant. Museum experiences are learning experiences, and what you call learning is of no consequence if learning is occurring (2002).

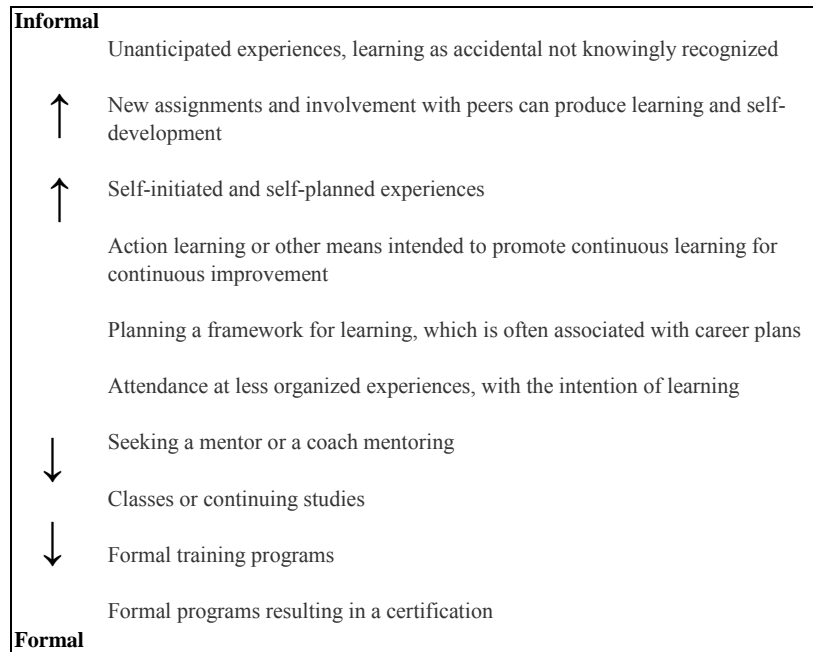


Figure 1. Formal and Informal Education Continuum. (Adapted from Stern and Sommerlad 1999)

The educational programming for *Beyond the Edge of the Sea* considered the implications of formal and informal learning. Due to the fact that visits to the exhibit will be planned by formal education institutions and visits will occur during official school hours, activities follow set objectives that correlate to national education standards. However, within the informal museum setting, unintended learning may occur.

Creating a Museum Experience

Many major museum exhibits today develop educational programming for specific audiences. All programs designed should be age appropriate, factual, and engaging. The

Interactive Experience Model developed by Falk and Dierking (2002) can be utilized to plan programming that suits the needs of visiting groups. This model is based on three overlapping contexts: Personal, Social, and Physical (Figure 2). Personal context refers to the anticipated outcomes each person has for his or her own museum visit, social context takes into account the interactions visitors have with others while at the museum, and physical context is the museum environment such as the buildings, architecture, and exhibit space. The overlapping of all three concepts creates an individual's interactive experience and gives museums a way to think about their visiting audiences and their perspectives in order to create effective programming.

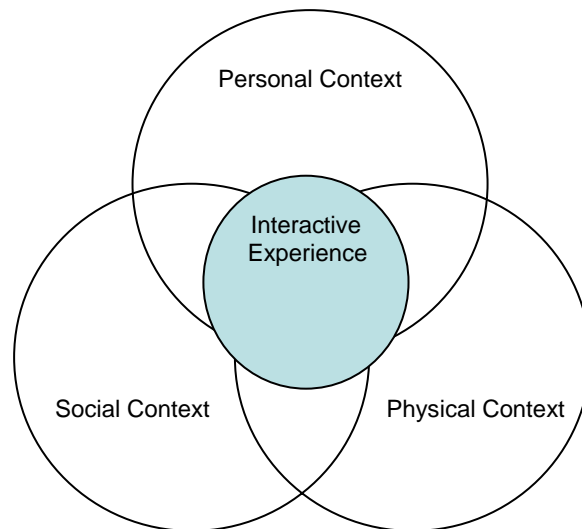


Figure 2. Interactive Experience Model (Falk and Dierking 2004)

There are eight guiding principles that fall within the Personal, Social and Physical contexts of the Interactive Experience Model, which aims to make sense of museum visits and experiences. These contexts can be viewed separately or as an integrated whole; all contribute to the success of an individual's total experience (Falk and Dierking 2002). The following is an explanation of the eight guiding principles and how they relate to the *Beyond the Edge of the Sea* exhibit.

Personal Context

Every museum visitor brings with them their own unique personal context, a combination of their interests, knowledge, motivations, and concerns. These things shape the type of experience an individual will have once inside a museum including their expectations and expected outcomes of their visit.

1. Personal pre-visit agenda will affect museum learning.

Many students will have preconceived notions about their upcoming museum trip. They may have had previous museum experiences or be influenced by friends and family members. Therefore, prior to arrival at an exhibit, students should be provided with pre-visit information. This pre-visit information will yield improved learning and retention after the museum experience. Students also benefit from information supplied before, during, and after a visit to the museum that emphasizes outcome or goals of visiting the exhibit. In addition, pre-trip preparation can create a mood of novelty for students, which will optimize learning for students while at the museum.

2. Learning styles and prior experiences affect how students learn within the museum setting.

Museums must go beyond traditional panels and docents for disseminating information. The psychologist Howard Gardner developed the “theory of multiple intelligences” that suggests students learn differently and school programming should include as many of these intelligences as possible (Gardner 2000). The intelligences he identifies are linguistic, logical-mathematical, bodily-kinesthetic, spatial, musical, interpersonal, intrapersonal, naturalist, and existentialist. Since children can have any combination of these intelligences, it is important to accommodate as many different learning styles as possible within museum programming.

All lessons should create connections to prior knowledge, especially those that have already been taught earlier in the school year. Museums have an interesting challenge in aligning their programs with visiting school curricula. Educational programming that connects new learning with what students already know facilitates greater learning outcomes.

3. Concrete information dissemination.

Museum visitors learn best when presented with concrete information that is presented in the absence of generalizations and abstractions. All curricular activities and information should be age-level appropriate. For elementary school aged children, this means no more than a few simple commands at one time. Young students work best with investigations that can physically be observed. Between fifth and eighth grade, students begin developing critical thinking skills, can understand abstract ideas, and realize their connection to the larger world. During these middle school years students can work on decision making activities and other more social initiatives. It is not until high school that students can analyze information, be persuasive in communication, and continue to strengthen problem-solving skills that apply to the real world (NAAEE 2004).

Personal Context: Implications for Beyond the Edge of the Sea Educational Programming

By providing an introductory lesson to be completed before a visit to the *Beyond the Edge of the Sea* exhibit, students will have a better sense of why they are attending the museum and what they can learn from going. I developed the lessons to address National Science Standards to ensure that they correlate to information being taught in schools, therefore increasing the likelihood that there is a connection between the exhibit and information they have previously been exposed to. In addition, activities take into account

the idea of multiple intelligences and incorporate them for each grade level. In the pre-exhibit lesson for Grades 3-5, students make a model of the ocean zones to understand the enormous depth of the ocean. This activity integrates several intelligences including logical-mathematical, linguistic, and spatial. Activities to be completed within the exhibit space ask students to work only with information that they can see in the illustrations, read off of panels and natural history brochures, or experience at supplemental stations. Activities stayed away from abstract ideas - students are not asked to synthesize information at the exhibit itself to assure the greatest learning potential while in the museum.

Social Context

4. Museum visits are social and individuals normally go in a group

When a student goes to a museum, it is normally with friends, teachers or family members. Automatically, the social dynamics of that group come into play. In most instances, children are more likely to remember who they were with at an exhibit rather than what the exhibit was about. Educational programming offered in this setting need to take these social cues into account and use these personal connections to their advantage. Many individuals can be uncomfortable in new situations and settings like museums (e.g., unfamiliar setting, dark, no seating). When programming integrates social interactions, discomfort can be alleviated allowing more learning to occur. Furthermore, children learn well together and should be given opportunities to work in groups when they are in the museum setting. This gives them the opportunity to talk about what they are seeing and share their ideas with peers.

5. *Museum professionals have an impact on the museum experience.*

Museum staff is an integral part of the success of any museum visitor's experience. Years after attending a museum exhibition, learners can recollect the quality of the docents they encountered. Moreover, contact between docents and a visitor that takes into consideration the individuality of that visitor increases the likelihood of a positive experience. Docents must also be dedicated, well versed in the exhibit material, and enjoy people in order to facilitate education.

Social Context: Implications for Beyond the Edge of the Sea Educational Programming

I considered social agendas when creating exhibit activities. Due to time restrictions placed on visiting school groups, social interaction activities were kept to only 10 to 15 minutes and could be completed in pairs or small groups. Unfortunately, since *Beyond the Edge of the Sea* is a traveling exhibit, there is no way in this project to guarantee the quality and availability of docents that may be at a particular site. However, the professional reputation of the institutions where the exhibit will be traveling leads me to believe learning will be enhanced by positive interactions between docents and students.

Physical Context

6. *Groups want to see the entire museum.*

Visitors who are scheduled to visit just one exhibit will undoubtedly want to see the rest of the museum. It is important to recognize that there is nothing you can do to dissuade them from this idea. However, knowing this and working with it is crucial. Students should be prepared ahead of time with a game plan that focuses first on the intended exhibit but lets them know that time will be allotted for a brief exploration of other exhibits. Though this

takes away from the intended purpose the field trip, it is nevertheless important to give this time so that frustration does not build and leave a learner with a negative experience.

7. The goal is to change attitudes.

Research conducted on attitudes of museum goers is unambiguous; strong feelings about school field trips are inevitable. The goal here is for learners to have a positive experience in the museum and therefore a positive recollection of the time spent there. However, with museums, the focus is on delivering information to visitors and not making certain that visitors have a positive reaction. Ideally, museums would provide both attributes, but since they are in juxtaposition to each other the museum and its programming is at a crossroads. It is difficult to balance between structured and unstructured time. It is the unstructured time that results in greater learner interest, though not factual knowledge.

8. Stimulation overload

In many cases museums provide a wealth of information. Children have a more difficult time than adults taking in stimuli and filtering it and this leads to a lack of focus. Both pre-trip preparation and allowing students some time to walk around and look at the exhibit can help overcome this obstacle. In addition, providing a structured activity will help to focus students and slow them down. In an ideal situation, groups would be able to visit an exhibit twice - once to get acquainted with the exhibit and adjust to the overwhelming amounts of information, and again to truly maintain focus on the purpose of their visit.

Physical Context: Implications for Beyond the Edge of the Sea Educational Programming

The activity developed for each grade levels exhibit activity takes into account many attributes of a museum's physical context. First, by providing students with an activity, they

will be able to focus on specific parts of the *Beyond the Edge of the Sea* exhibit, which will serve to orient them within the museum space and alleviate any sense of agitation they may feel being in an unfamiliar space. Activities developed are simple and do not require much time to accomplish. This will allow time for students to explore the rest of the exhibit as well as other areas in the museum, keeping their frustration low and interest high.

Curriculum Programming

The development of the educational programming for *Beyond the Edge of the Sea* relied on the collaboration of many individuals. Those most closely involved were Cindy Van Dover from the Duke Marine Lab, JoAnne Powell and Allison Besch from the North Carolina Maritime Museum, and John Bain and myself, both Environmental Management Master's students from Duke University. Given that the North Carolina Maritime Museum's mission is to "interpret ... coastal cultural heritage and its natural and maritime history through collections, research, exhibits, and educational programs" (NC Maritime Museum 2007) JoAnne and Allison were an invaluable resource while developing the educational materials for this exhibit.

Ideas for the education materials began with brainstorming sessions between John Bain and me. We then presented our ideas to the group and they accepted, reworked, or scratched them altogether. Once we agreed upon basic ideas for each grade level I began writing lessons. Groups meetings continued and everyone provided us with feedback, constructive criticism, and focus needed as lessons began to take shape. As a result, we developed age appropriate lessons designed specifically for Grades K-2, 3-5, 6-8 and high school.

In the beginning of each lesson plan is a list of both the National Science standards and Ocean Literacy standards that will be addressed in that lesson. For each grade level, we created a pre-exhibit activity, exhibit activity and post-exhibit activity. The pre-exhibit activity is intended to familiarize students with concepts and general terminology in preparation for visiting the exhibit. Depending on the grade level there may be more than one. Exhibit activities were designed to be short and incorporate the connections between art and science. Finally, post-exhibit activities are meant to be completed following a visit to the exhibit to review key points. Each lesson plan begins with teacher background to provide information that he/she should be familiar with before teaching that particular lesson. This is followed by the lesson objective, materials needed, and the amount of time needed to implement the lesson. The next part of the lesson is the procedure which breaks down the instructions that the teacher is to follow. Additional resources and links to more information and other lesson plans are also provided for the teacher who wants to find more information or access more lessons to expand the idea of deep sea environments in his/her own classroom.

To have the most relevancy and draw for formal educators, the lessons created are correlated to the Ocean Literacy Standards (Table 1) as well as National Science Education Standards (NSES) created by National Research Council (Table 2). Though there are no federally sanctioned education, the NSES were compiled in 1995 and published in 1996, the culmination of a four year collaboration between over 22 scientific and science education societies and over 18,000 individual contributors (NSTA 2008). These standards are not a compilation of lesson plans or a set curriculum; they are the guiding goals for science education. The lessons for *Beyond the Edge of the Sea*, where appropriate, were made interdisciplinary.

Table 1. Ocean Literacy Standards addressed in each lesson.

Lesson	Ocean Literacy Standard						
	1. Earth has one big ocean with many features.	2. The ocean and life in the ocean shape the features of Earth.	3. The ocean is a major influence on weather and climate.	4. The ocean makes Earth habitable.	5. The ocean supports a great diversity of life and ecosystems.	6. The ocean and humans are inextricably linked.	7. The ocean is largely unexplored.
K-2							
Pre-Activity						x	
Visit Activity					x		
Post-Activity						x	
3 to 5							
Pre-Activity					x		x
Visit Activity						x	
Post-Activity						x	
6 to 8							
Pre-Activity					x		
Visit Activity					x		x
Post-Activity	x				x		x
HighSchool							
Continuous Activity					x		x

Table 2. National Science Standards addressed in each lesson.

Lesson	National Science Education Standards						
	Science as Inquiry	Physical Science	Life Science	Earth and Space Science	Science and Technology	Science in Personal and Social Perspectives	History and Nature of Science
K-2							
Pre-Activity	x				x		
Visit Activity			x				
Post-Activity						x	
3 to 5							
Pre-Activity		x	x				
Visit Activity							x
Post-Activity							x
6 to 8							
Pre-Activity		x	x				
Visit Activity							x
Post-Activity						x	
HighSchool							
Continuous Activity	x			x	x		

As lessons neared completion, the North Carolina Maritime Museum distributed them to local educators for assessment and review. These educators were chosen on the basis that they work closely either with ocean science or the intended age group for the

particular lesson plan. The group reviewed written comments and suggestions made by educators and changes deemed appropriate were identified and implemented.

Next Steps and Application

At this point in time, developed educational materials for Grades K-2, 3-5, 6-8, and 9-12 will be sent to the North Carolina Maritime Museum. The North Carolina Maritime Museum's education coordinators will make final reviews and edits using their expertise as museum educators. Upon completion of the final edit, all activities will be given to the graphics department at the Muscarelle Museum at the College of William and Mary for final formatting and preparation for publication. All educational materials will be available on the Muscarelle website for teachers to access. I recommend that as teachers make reservations to visit the exhibit that museum staff direct them to these web resources. This will allow utilization of the lesson plans available and provide teachers with time to plan when and how they will implement lessons.

Though not explicitly stated in the education materials, I suggest that teachers take time with their students before visiting the exhibit to prepare for the trip. This should include providing students with an itinerary to mentally prepare them for how the day will run. This way, they will know how much time has been dedicated to the exhibit and how much is left over to explore on their own. This will focus students while in the *Beyond the Edge Sea* exhibit, and motivate them while they work on the exhibit activity.

Supplying students with a map may also be useful in preparing for the field trip. Students who are anxious about going somewhere new may be put at ease if they are familiar with the layout of the museum. Examining a map and locating the exhibit hall, gift shop, bathrooms, or other areas of interest will serve to reduce stress in relation to this trip.

Finally, I encourage teachers to use this exhibit and educational materials as a jumping off point for teaching ocean literacy in their own classrooms. Currently, ocean science is under represented in our nation's schools. There are great opportunities to increase awareness and interest in marine science and integrate them into the curriculum. Perhaps *Beyond the Edge of the Sea* will inspire teachers to encourage their students to become stewards of the deep sea.

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Appendix

Appendix A: K-2 Lesson Plan

**Beyond the Edge of the Sea
Grades K-2 Pre-exhibit Activity**

Title: “Tools of the Trade”

Summary: Students will learn about the tools that scientists and artists use. This activity is an introduction to the *Beyond the Edge of the Sea* exhibit and serves to familiarize students with the collaboration that take place in science.

Background: Scientist try to answer questions and better understand the world we live by using appropriate tools. Students should know that scientist use tools to investigate and experiment. This allows them to broaden their ability to observe. Observing is an important method in science, making careful sketches of what is observe is a way for scientist and in the case of this exhibit artists to communicate their observations.

Objective: Students will learn that different professions use different tools to accomplish their jobs. They will sort tool and decide which professional uses which tools.

Grade level: K-2

Setting: Classroom

Duration: 30 minutes

Key words: job, tools, oceanographer, vessel, easel, microscope, magnifying glass, camera and submersible.

National Science Standards met:

CONTENT STANDARD A: SCIENCE AS INQUIRY

- Simple instruments, such as magnifiers, thermometers, and rulers, provide more information than scientists obtain using only their senses

CONTENT STANDARD E: SCIENCE AND TECHNOLOGY

- Tools help scientists make better observations, measurements, and equipment for investigations. They help scientists see, measure, and do things that they could not otherwise see, measure, and do.

Ocean Literacy Standards met.

6. THE OCEAN AND HUMANS ARE INEXTRICABLY INTERCONNECTED.

- b. From the ocean we get foods, medicines, and mineral and energy resources. In

addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.

Materials:

Worksheet
Scissors
Glue

Procedure:

1. Ask students to name different jobs you could have that work with the ocean. (Some examples might be fisherman, captains, navy, coast guard and marine biologists) make sure that they list both scientist/oceanographer and artists.
2. Tell students that soon they will be going to a museum exhibit that was put together by an artist and an oceanographer who worked together to observe the animals that live in the deep ocean.
3. Tell class that in order to do their job scientist and artists (along with all other professions) require the use of tools. Have students volunteer the tools they use to be good students. Just as students have tools they need in order to do well in school. Artist and scientists also use tools to do their work.
4. Pass out worksheets, go over directions. Students complete sheet.
5. Review student responses and discuss how they use their tools.

Resources:

<http://www.whoi.edu/page.do?pid=8422>

<http://iodeweb5.vliz.be/oceanteacher/resources/other/AndersonBook/ToolsOc.htm>

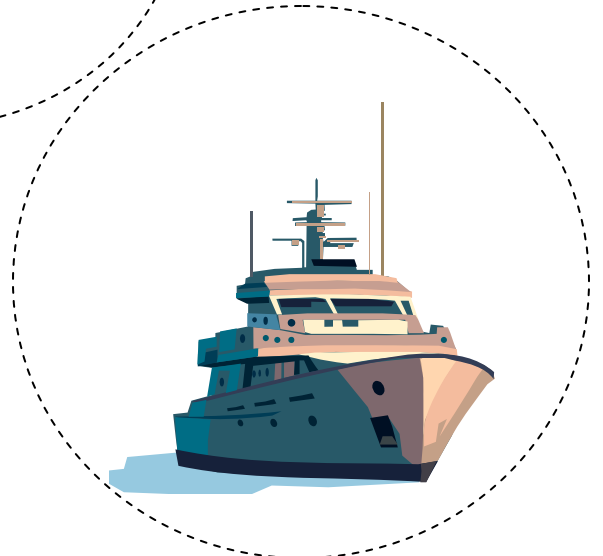
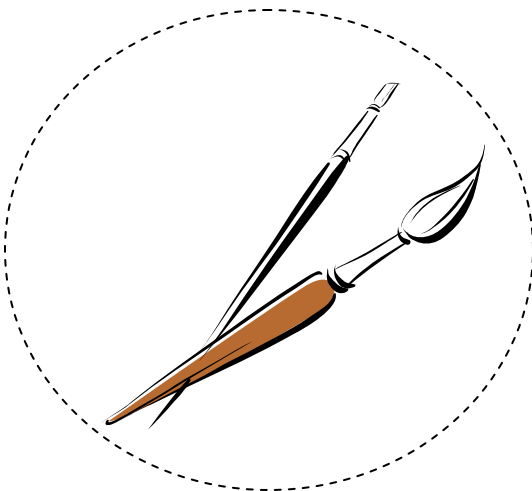
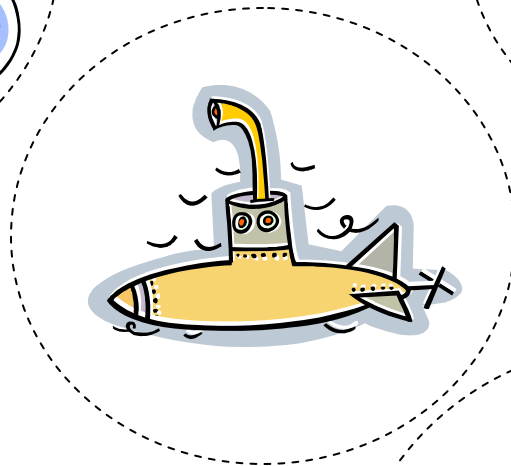
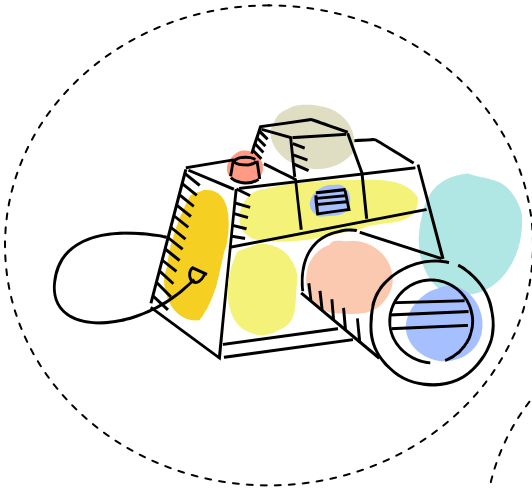
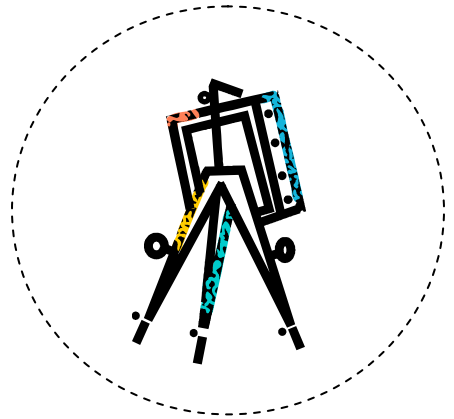
<http://www.proteacher.com/cgi-bin/outside.cgi?id=89&external=http://www.whoi.edu/k-12/&original=http://www.proteacher.com/110054.shtml&title=Woods%20Hole%20Oceanographic%20Institution:%20K-12%20Education>

Name _____

Date _____

Cut out the tools that are used by scientists who study the ocean and artists. Paste the tools under who you think works with that tool.

Scientist	Both	Artist



Beyond the Edge of the Sea: Grades K-2 Exhibit Activity

Title: “Treasure Hunt”

Summary: In this activity students will hunt for the different deep sea animals in the *Beyond the Edge of the Sea* exhibit this will raise awareness to the range of animals that are found in the deep sea.

Background: Deep sea ecosystems are unlike anywhere else on earth. The animals found there were only discovered in the late 1970’s therefore, there is a still lot to learn about them. The diversity of fauna found on at hydrothermal vent sites is astounding the best way students to learn about these communities is to make observations of ecosystems. Unfortunately you can’t very few get to travel to the bottom of the ocean so this exhibit is a great way to show students what can be found down there.

Objective: Students will observe focal art pieces and identify properties of the animals in the painting to the ones on their map to determine if they are the same.

Grade level: K-2

Setting: *Beyond the Edge of the Sea* exhibit space

Duration: 30 minutes

Key words: Shrimp, crab, fish, snail, mussel, worm

National Science Standards met:

CONTENT STANDARD C: LIFE SCIENCE

- Each plant or animal has different structures that serve different functions in growth, survival, and reproduction. For example, humans have distinct body structures for walking, holding, seeing, and talking.

Ocean Literacy Standards met.

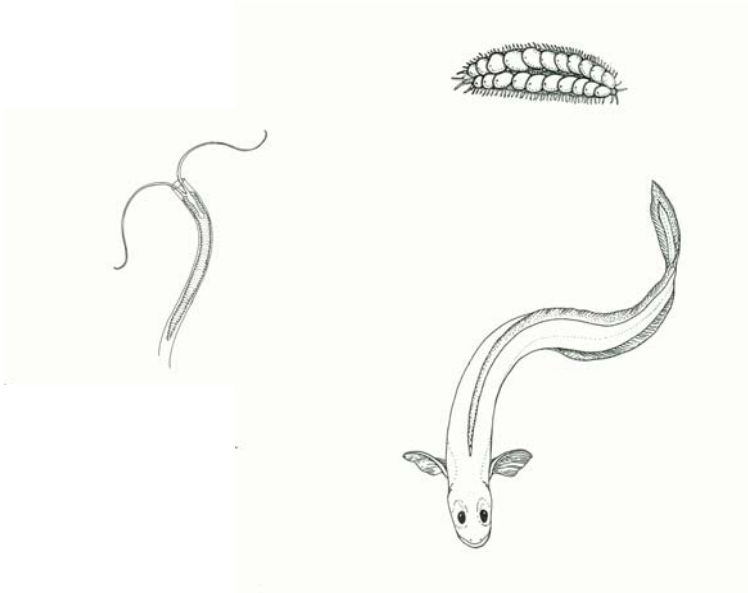
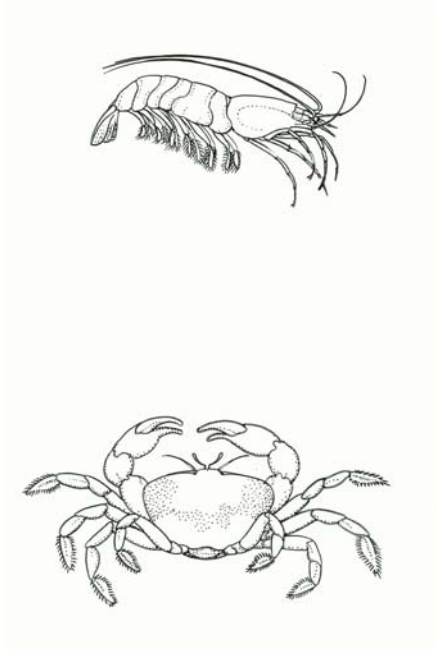
5. THE OCEAN SUPPORTS A GREAT DIVERSITY OF LIFE AND ECOSYSTEMS.

- c. Some major groups are found exclusively in the ocean. The diversity of major groups of organisms is much greater in the ocean than on land.

Procedure:

- Hand each student a Treasure Hunt map, and assign students to work in pairs.
- Students will search exhibit for the animals on their treasure map.
- Students will place a checkmark next to the image on the map as they find each animal.

**Beyond the Edge of the Sea:
Treasure Hunt Map**



Do any of these animals live anywhere but the ocean? _____

My favorite animal in the exhibit is _____.

Draw a picture of this animal below



Beyond the Edge of the Sea Grades K-2 Post-exhibit Activity

Tile: “A Drop in the Ocean?”

Summary: Students will add materials to a model ocean and see that it results in an environment that may be harmful to the animals that live there.

Background: Ocean pollution is nothing new. For centuries humans who traveled the seas or lived on the coasts have been discarded trash into the ocean. This has negative effects and can harm the animals that live in the ocean environment. Trash in particular can cover animals and smother them, while others ingest trash which can choke them and lead to their death. Some garbage contains heavy metals which then accumulate on the sea floor. If students know how the ocean is polluted they can choose not to partake in these activities.

Objective: Students will learn that people can change the environment and that their actions have consequences.

Grade: K-2

Setting: Classroom, students need easy access from their seats to the front of the class.

Duration: 20-30 minutes

Key words: pollution, waste, litter

National Science Standards met:

CONTENT STANDARD F: SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES

- Changes in environments can be natural or influenced by humans. Some changes are good, some are bad, and some are neither good nor bad. Pollution is a change in the environment that can influence the health, survival, or activities of organisms, including humans.

Ocean Literacy Standards met:

6. THE OCEAN AND HUMANS ARE INEXTRICABLY INTERCONNECTED.

e. Humans affect the ocean in a variety of ways. Laws, regulations and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (point source, non-point source, and noise pollution) and physical modifications (changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean.

g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Materials:

Clear glass beaker
Water.
Dixie cups (1 per student)
Soil
Instant coffee
Vegetable oil
Shredded paper.
Thread/fishing line

Preparation: Fill beaker half way with water. Put soil, instant coffee, vegetable oil, paper, and thread into cups.

Procedure:

1. Ask students to share what their favorite deep sea animal was from the exhibit.
2. Tell them that in order to protect these animals we have to take care of our oceans. One way to do this is to not pollute.
3. Hand out one Dixie cup per student. The materials in the Dixie cup represent pollutants that can get into the ocean.
 - Construction site - Soil
 - Farms animal waste - Coffee grinds
 - Motor oil - Vegetable oil
 - Litter - Shredded paper
 - Fishing line - Thread/fishing line
4. Talk about pollution
5. Call up students with waste from the construction site to add soil to the water. When workers dig holes the dirt becomes loose and it gets carried away to the ocean making the water unclear.
6. Call up the students with coffee grinds. Tell the class that some farms have a lot of animals that create a lot of waste. This manure is carried by rain water to rivers all the way to the ocean,
7. Call up the students with vegetable oil. Sometimes boat that cruise on the water leave behind oil from their engines.
8. Call up students with the shredded paper. This is trash left at the each by picnickers who did not throw their trash away.
9. Call up students with the fishing line, sometimes people who fish break their fishing line and it stays in the water.

Discussion questions:

What can you do to take care of the ocean?

Why is it important to be concerned about the ocean? What does the ocean provide you with that it might not in the future if people don't care for it?

Resources:

http://library.thinkquest.org/CR0215471/ocean_pollution.htm

<http://www.cdli.ca/CITE/oceanpollution.htm>

http://www.motherjones.com/news/featurex/2006/03/marine_pollution.html

<http://www.cleanoceanaction.org/>

<http://www.surfrider.org/whatwedo2a.asp>

Appendix B: 3-5 Lesson Plan

Beyond the Edge of the Sea: Grades 3-5 Pre-Activity

Title: “Water Runs Deep”

Summary: Students will learn about the different ocean zones and where they are located in the ocean. This activity is an introduction to the *Beyond the Edge of the Sea* exhibit and serves to familiarize students to the concept of how deep the animals they will see in exhibit are found.

Background: Sun light does not penetrate to the bottom of the ocean. Light penetration in coastal waters is less than the open ocean. This is due to the humic acid, particulate matter and plankton found in the water. The open ocean has less of these materials and allows for light to penetrate to approximately 200 meters. The ocean is divided into five main zones.

- The **epipelagic** zone is the top layer of water and reaches until sunlight penetration dissipates at about 200 meters. It is at this point that plants can no longer carry out photosynthesis.
- Below this zone is the **mesopelagic** zone which extends from 200 meters to 1,000 meters. Many organisms such as squid and small fish spend their days here and travel to the surface at night to feed on plankton.
- The **bathypelagic** zone continues downward until 4,000 meters. This zone is completely dark with the exception of bioluminescence created by organisms like the angler fish which generate their own light.
- Beyond the bathypelagic zone, when the ocean floor topography begins to flatten out is the **abyssopelagic** zone, typically this zone reaches the ocean floor approximately 6,000 meters below sea level. Temperatures here are close to freezing and few animals can be found.
- Ocean trenches are the deepest places of the ocean, these trenches that occur in areas of tectonic subduction, are referred to as the **hadal** zones, but will not be discussed in the following activity.

Objective: Students will create a scale model of the ocean's many zones. They will also mark where there is no longer light penetration to show that most of the ocean is dark and void of sunlight.

Grade level: 3-5

Subject areas: physical science and math

Duration: Approximately 30 minutes. Extension activity will take longer and require at least a 45 minute class period.

Setting: Classroom, no special seating arrangement required.

Keywords: Hydrothermal vent, epipelagic, mesopelagic, bathypelagic and abyssopelagic.

National Science Standards met:

CONTENT STANDARD B: PHYSICAL SCIENCE

- Objects have many observable properties, including size, weight, shape, color, temperature, and the ability to react with other substances. Those properties can be measured using tools, such as rulers, balances, and thermometers.

Ocean Literacy Standards met:

7. THE OCEAN IS LARGELY UNEXPLORED.

e. Use of mathematical models is now an essential part of ocean sciences. Models help us understand the complexity of the ocean and of its interaction with Earth's climate. They process observations and help describe the interactions among systems.

Materials:

Register Tape
Calculators
Rulers
Markers

Procedure:

1. Break students into groups of four. Provided each group with 1 meter of register tape.
2. Tell students that the tape represents the distance from the ocean surface to the ocean floor. The distance from the ocean surface to the sea floor is divided into sections and given names. Provide students with zone names, initial depth and final depth for each zone.
3. Next tell students how many cm each zone is on their tape. And have them measure it out.

Zone	Beginning depth (m)	Ending Depth (m)		Answers
epipelagic	Sea level	200		3 cm
mesopelagic	200	1,000		16. 7cm
bathypelagic	1,000	4,000		66.7cm
abyssopelagic	4,000	bottom		1 m

4. Discuss with students that light does not penetrate all the way to the bottom of the ocean; all light has been absorbed by 200 m. Students should realize that this is the bottom of the epipelagic zone. Have each group draw a crossed out light bulb at the 200 m mark. In addition, hydrothermal vents occur at around 2500 m below the surface. Calculate and draw a star on the register tape where vents are located (41.7 cm from the top).

Extension:

As an extension activity students can calculate the depth of each zone as it will appear on their meter of register tape. They are converting meters to inches. In order to do this calculation students will need the zone name, beginning depth and ending depth. Once calculations are made students will measure and mark on the register tape where the zone boundaries are located.

Conversion calculation example:

Each group of students has 1 meter of tape. Each meter represents 6,000 meter. Conversion requires cross multiplying.

Ex. Calculations for the bottom of the epipelagic zone.

$$(200 \text{ meters of sea}) \times (1 \text{ meter of tape} / 6000 \text{ meters of sea})$$

In essence you are dividing 200 by 6000. This gives the quotient 0.03. To convert this answer to cm multiply by 100, this equals 3cm. Students would then place a line 3 cm below “sea level” on their register tape, indicating the bottom of the epipelagic zone.

Closing discussion::

Q: What is the largest zone in the ocean? Which is the smallest?

A: Largest is the bathypelagic. Smallest is the epipelagic.

Q: How do you think the mesopelagic and bathypelagic zones are similar? How are they different?

A: Both are below the zone where light penetrates. Therefore it is dark in both places. Since the mesopelagic zone is below the epipelagic zone where there is light, animals that live there could travel up to the areas where there is light and interact with the organisms in that zone. Traveling into the epipelagic zone allows access to the area where photosynthesis occurs which could provide both phytoplankton and zooplankton as prey. The bathypelagic zone is also larger than the mesopelagic zone.

***Q: In which zone do you think you will find more living animals?
Why?***

A: Answers will vary.

L.A. extensions: Research the prefixes epi, meso, bathy, and abyss for each ocean zone, as well as the root pelagic. Have students draw images that they think represent the meaning of each ocean zone.

Resources:

<http://www.aquatic.uoguelph.ca/oceans/Introduction/Zonation/zonation.htm>

Quick overview of ocean zones provides basic scientific terms that include the horizontal as well as the vertical ocean zonation.

<http://www.mbgnet.net/>

Includes information on the different biomes of the world, including the marine environment. Good source for basic data and easy to understand pictures.

Deep Sea Creatures

<http://www.teara.govt.nz/EarthSeaAndSky/SeaLife/DeepSeaCreatures/1/en>

This site provides detailed description of both the mesopelagic and bathypelagic zones, including general statistics and adaptations of the fauna found there as well as life found on the sea floor. In addition there is historical information pertaining to the exploration of the seas.

Exploring the Deep Frontier

<http://www.ocean.udel.edu/extreme2004/home.html>

The University of Delaware provides information on the technology and equipment that is used to explore hydrothermal vents, as well as other ocean floor geologic , they even provide virtual expeditions.

National Weather Service: Layers of the Ocean

http://radar.weather.gov/jetstream/ocean/layers_ocean.htm

Offers short descriptions of each of the ocean zones. Includes discussion about light and temperature.

Beyond the Edge of the Sea Grades 3-5 Pre Activity

Title: Under Pressure

Summary: Students will see the effects of pressure on different materials and realize that there is more pressure on the ocean floor than on land. This activity is an introduction to the *Beyond the Edge of the Sea* exhibit and serves to familiarize students to the characteristics of the environment that deep sea animals have adapted too.

Background: Pressure is measured in units known as atmospheres (atm). At sea level the pressure equals 1 atm. For approximately every 10 meters of depth the pressure increases by 1 atm. If the sea floor is at 6,000 meters, the pressure there is 600atm! Many organisms in the ocean have bodies that are made mostly of water, since liquids do not compress well these animals are largely unaffected by the pressure. However some fish have an organ called a swim bladder. This organ adds or subtracts gas from the bladder to regulate their buoyancy in the water column.

Objective: Students will hypothesize about what happens to different objects when they are subjected to extreme pressure. They will think about adaptations that some animals have made to adapt to pressure.

Grade level: 3-5

Subject areas: physical science

Duration: 15- 20 minutes

Setting: Classroom (no special set up required).

Key words: pressure, compress and volume

National Science Standards met:

CONTENT STANDARD B: PHYSICAL SCIENCE

- Objects have many observable properties, including size, weight, shape, color, temperature, and the ability to react with other substances. Those properties can be measured using tools, such as rulers, balances, and thermometers.

Ocean Literacy Standards met:

5. THE OCEAN SUPPORTS A GREAT DIVERSITY OF LIFE AND ECOSYSTEMS.

f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is

“patchy”. Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.

Materials:

Styrofoam packing peanuts
Activity Sheet

Procedure:

1. Begin with a brief discussion on pressure. Ask students what they know about it and write ideas on the board.
2. Take out Styrofoam packing peanuts. Discuss characteristic of the peanuts.
3. Give each student a packing peanut and have them exert pressure on it. They may choose to stand on it, place books on top of it etc. Discuss what happened
 - Packing peanut flattened
 - Packing peanuts contain a lot of air when pressure is placed on it the air compressed and the peanut take up less volume.
4. Think about the depth of the ocean (from the last activity) and how much pressure there is from the water above (approximately 4,000,000 pounds). Do the students think that the packing peanuts would remain intact in the deep sea environment?
5. Students complete worksheet. (See Attached)

Resources:

PBS Online - Savage Seas

<http://www.pbs.org/wnet/savage seas/deep-side-journey.html>

This site covers topics including survival beneath the sea and expeditions to the deepest part of the ocean. Animations and video clips are also available; be sure to check out the deep sea simulator.

Mar-Eco

http://www.mar-eco.no/learning-zone/backgrounders/oceanography/deepsea_challenges

Covers deep-sea challenges, including pressure, temperature and light. Pictures are provided of the pressure effects on fish that have swim bladders and were removed from their habitat.

Deep Sea Pressure

http://www.montereybayaquarium.org/video/video_popup_dsc_pressure.asp

Video demonstration of the effects of pressure on a Styrofoam cup, as a ROV descends down the water column.

The Natural History Museum – Deep Ocean


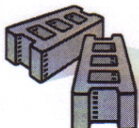


<http://www.fathom.com/course/10701050/session1.html>

Provides an overview of the buoyancy mechanisms that limit fish in shallower waters as compared to those found in deeper water.

Name _____

Date _____

What do you think will happen to these objects if they were on the sea floor? After thinking about each object, record characteristics of the object as it looks on land. Then imagine that same object at the bottom of the ocean under a lot of pressure. Finally, compare the object. Record your answers in the table below.

Object	Initial Observations.	Hypothesized observations under pressure.	Was there a change? Explain your answer.
Golf ball 			
Brick 			
Aluminum can 			
Balloon 			

Some fish have swim bladders, a gas filled sac inside their body that helps them control the depth they swim in. However, not all fish have this organ. Why do you think this is? Where might you find fish that have swim bladders? When would a fish not want one?

**Beyond the Edge of the Sea:
Grades 3-5 Pre-Activity**

Title: “In Hot Water”

Summary: Students will calculate water temperatures that hydrothermal vent animals live in. This activity is an introduction to the *Beyond the Edge of the Sea* exhibit and serves to familiarize students to the characteristics of the environment that deep sea animals have adapted too.

Background: The top layer of the ocean is well mixed; while the bottom water in the ocean is fairly uniform in temperature and cold. Between these two layers is a transition zone known as the thermocline; in this area there is a rapid decline in water temperature. The typical temperature of the ocean floor ranges from 2-3 degrees C. However, hydrothermal vent areas have temperatures reaching close to 350° C. The organisms that live in hydrothermal vent communities do not reside in this super hot water, rather they are found in the ambient water where temperatures are much cooler.

Objective: Students will calculate the range of temperatures that deep sea organisms live in.

Subject areas: life science and math

Duration: 15-20 minutes

Setting: Classroom (no special set up required)

Key words: ambient heat, range, hydrothermal vent, average

National Science Standards met:

CONTENT STANDARD C: LIFE SCIENCE

- Organisms have basic needs. For example, animals need air, water, and food; plants require air, water, nutrients, and light. Organisms can survive only in environments in which their needs can be met. The world has many different environments, and distinct environments support the life of different types of organisms.

Ocean Literacy Standards met:

5. THE OCEAN SUPPORTS A GREAT DIVERSITY OF LIFE AND ECOSYSTEMS.

f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is “patchy”. Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.

Materials:

Work sheet - Temperature data from a hydrothermal vent.

Procedure:

1. Tell students that the bottom of the ocean is very cold. Only 2-3° C! But some animals live near hydrothermal vents where hot water comes out through the ground. Hand students vent data sheet , and let them know that these animals all live near vents where the hot and cold water mix.
2. Have students use the data for each organism to calculate the average temperature and temperature range of each organism.

Questions for Discussion:

What organisms can be found at the highest temperatures?

What organisms if any have overlapping temperature ranges?

Put these organisms in order ranging from those you think are found closest to vents to those found furthest away.

Some of these animals live in locations where the temperatures vary. For example *Alvinellid Polychaetes* live in tubes where the front end is open to water that is 20°C and the back end is open to water that is 60°C. If you were the scientist taking samples, how would you deal with this problem?

Resources:

<http://www.lakefortkansas.com/Pages/therm.html>

Explains the concept of a thermocline using fishing in Lake Fort as an example. Progresses through how seasonal variation alters the layers of the lake and how this effects the thermocline.

Nemo Net

<http://www.pmel.noaa.gov/vents/nemo/realtime/tempdata.html>

Collection of temperature data taken at hydrothermal vents using probes over the course of three years.

Windows to the Universe

<http://www.windows.ucar.edu/tour/link=/earth/Water/temp.html&edu=high>

Discussed the temperature of ocean water on three levels: beginner, intermediate and advanced. Briefly explains ocean stratification, salinity and circulation.

Name _____

Date _____

Below is a table of organisms found living near hydrothermal vents. Temperature data was collected as each organism was sampled, the temperatures are recorded below. Use the data to determine the average water temperature and range where each animal is found.

	Water Temperature °C								Average	Range
<i>Rijia parviflora</i> Tube worms	2.4	2.1	4.5	3.6	7.5	10.5	4.0	5.8		
<i>Calypogena magnifica</i> Giant clam	4.6	.9	2.4	14	3	4.6	9	8.8		
<i>Bathymodiolus thermophilus</i> Vent Mussels	5.7	6	6.3	5.8	7.1	5.5	7.4	4		
<i>Alvinella</i> Polychaetes Worm	31.6	34.7	29.4	35.6	39.3	40	37.6	38.2		

What organisms can be found at the highest temperatures?

What organisms if any have overlapping temperature ranges?

Put these organisms in order ranging from those you think are found closest to vents to those found furthest away.

Some of these animals live in locations where the temperatures vary. For example *Alvinella Polychaetes* live in tubes where the front end is open to water that is 20°C and the back end is open to water that is 60°C. If you were the scientist taking samples, how would you deal with this problem?

Beyond the Edge of the Sea: Grades 3-5 Exhibit Activity

Title: “State of the Art”

Summary: Students will respond to art illustrations that portray science. This activity is intended to occur while visiting the *Beyond the Edge of the Sea* exhibit.

Background: The illustrations in the exhibit are the result of a fifteen-year collaboration between Cindy Van Dover, a deep sea biologist and hydrothermal vent expert, and watercolor illustrator Karen Jacobsen. The two women decided to bring their unique talents together to educate others about the existence of extreme deep ocean environments. Show-casing the beauty of the deep sea through art is a way for the public to be exposed to the inaccessible reaches of ocean. Dr. Cindy Van Dover, the director of the Duke Marine Lab, expert on hydrothermal vent communities, and curator of this exhibit states “If we omit this style of observation and documentation from our scientific agenda, we have lost part of our heart; we are poorer for it.”

Objective: Students will observe the major focal pieces of *the Beyond the Edge of the Sea* exhibit and react to the art work by recording words that they associate to the art.

Subject areas: life science, art

Duration: 10-15 minutes

Setting: *Beyond the Edge of the Sea* exhibit space.

Key words: See word bank

National Science Standards met:

CONTENT STANDARD G: HISTORY AND NATURE OF SCIENCE

- Science as a human endeavor

Ocean Literacy Standards met:

6. THE OCEAN AND HUMANS ARE INEXTRICABLY INTERCONNECTED.

- c. The ocean is a source of inspiration, recreation, rejuvenation and discovery. It is also an important element in the heritage of many cultures.

Materials:

Clip board
pen/pencil

Procedure:

1. Hand students Focal Piece worksheet and explain directions
2. Assign small groups of students to start at different focal pieces so they have enough room to observe the piece.

Closing Discussion:

Students share their thoughts and observations about the exhibit.

Name _____

Date _____

Examine each of the focal pieces in the exhibit. Think about each piece and how it connects to you on an emotional level. Then look at the piece again and consider how it conveys scientific information. Choose words from the box below or write in your own words that describe each of the focal pieces.

Focal Pieces:

Black Smoker



Tubeworms



Mussel Bed Community



Tui Malila



Moose



Word Bank: ecology	lively	colorful	inspiring	curious	motion	space
personality	logical	simple	orderly	chaotic	investigative	ideal
uncertainty	scale	contradiction	natural	harmony	picturesque	calm

**Beyond the Edge of the Sea
Grades 3-5 Post Visit Activity**

Title: “Diversity is the Spice of Life”

Summary: Students react to the exhibit they went to the day before and create their own definition of biodiversity.

Background: Biodiversity is the variety of life on earth. This includes all living things and the ecological communities they live in. Preserving living organisms and their habitats may provide us with the opportunity to make new discoveries. Species are going extinct faster than we are discovering them. Conserving biodiversity will ensure that there are enough resources such as food, medicine and supplies for manufacturing to maintain and support human life.

Objective: Students will compare different organisms and come up with definitions of biodiversity. They will also write an example of biodiversity using examples they saw in the exhibit.

Grade level: 3-5

Subject area: Life science

Duration: Approximately 30 minutes.

Setting: Classroom (no special set up required).

Keywords: diversity, biodiversity

National Science Standards met:

CONTENT STANDARD C: LIFE SCIENCE

- Each plant or animal has different structures that serve different functions in growth, survival, and reproduction. For example, humans have distinct body structures for walking, holding, seeing, and talking.

Ocean Literacy Standards met:

5. THE OCEAN SUPPORTS A GREAT DIVERSITY OF LIFE AND ECOSYSTEMS

- g. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, methane cold seeps, and whale falls rely only on chemical energy and chemosynthetic organisms to support life.

Procedure:

1. Discuss with students their general reactions from the exhibit.
2. Students recall some of the organisms they saw in the illustrations they day before. Make a list on the board, draw comparisons about how these deep sea animals are different than the ones that are found in shallower water. (You can reference the natural history brochure available online to help in this activity).
3. After comparing organisms as a class, have students take 2-3 minutes to write their own working definition of biodiversity. Have students volunteer to share their ideas and as a class come up with a working definition of diversity. Biodiversity is the variety of life on earth.
4. At this point divide the class into 12 groups.
5. Give each group a card with one of the letters of BIODIVERSITY on it.
6. Students will brainstorm things about the exhibit and come up with a statement that begins with their letter.
7. Each group will have a volunteer to stand and recite their sentence to spell out the word.

Discussion questions to consider:

1. How can similar animals live in different places?
2. How do you think animals came to live at hydrothermal vents?
3. Why do you think deep sea shrimp are located only around hydrothermal vents?

Resources:

Biodiversity Project

<http://www.biodiversityproject.org/>

Group of individuals who work to make people aware of the importance of biodiversity and build their commitment to saving it.

Stanford encyclopedia of Philosophy

<http://plato.stanford.edu/entries/biodiversity/>

Lists concepts of biodiversity and species value.

The Science Spot

<http://sciencespot.net/Pages/nclsslks.html>

Web page that links to other biodiversity lesson plans.

Appendix C: 6-8 Lesson Plans

Beyond the Edge of the Sea: Grades 6-8 Pre-Activity

Title: “No Sugar Added”

Summary: Students will compare the differences in two energy producing processes: photosynthesis, which occurs in the presence of light, and chemosynthesis, which occurs at hydrothermal vents. This activity is an introduction to the *Beyond the Edge of the Sea* exhibit and serves to familiarize students to the chemosynthetic communities they will see in exhibit’s art illustrations.

Background: Until the 1970’s it was believed that the only source of energy making life possible originated from the sun. With the discovery of hydrothermal vents and the communities that thrive there, that idea was shaken. Here communities received energy for life from a process known as chemosynthesis. Instead of using sunlight to create energy, bacteria were converting heat and vent chemicals that came from the earth’s interior.

Photosynthesis is the process by which a plant produces its own food in the form of the sugar glucose. Plants use energy from sunlight, carbon dioxide, and water taken in through its root system to produce oxygen and glucose. Since photosynthesis is sunlight dependent, it only occurs on land in shallow water. .

Chemosynthesis is the process by which food in the form of the sugar (glucose) is made by bacteria. Instead of using light as an energy source, the bacteria uses chemical available from a source such as hydrothermal vent water. Chemosynthesis can occur not only at vents but also at cold water seeps and whale falls – all places where sunlight is absent. Bacteria that live on the sea floor or within deep sea animals make glucose out of carbon dioxide, water and hydrogen sulfide.

Objective: Students will learn about and compare the processes of photosynthesis and chemosynthesis. They will sequence the steps involved in each process and discover that they both produce usable energy.

Grade level: 6-8

Subject areas: marine science, chemistry, life science.

Duration: Approximately 45 minutes.

Setting: Classroom

Keywords: photosynthesis, chemosynthesis, communities, ecosystems, equations, hydrothermal vent, chemical equation, bacteria.

National Science Standards met:

CONTENT STANDARD B: PHYSICAL SCIENCE

- Substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristic properties. In chemical reactions, the total mass is conserved. Substances often are placed in categories or groups if they react in similar ways; metals is an example of such a group.

CONTENT STANDARD C: Life Science

- For ecosystems, the major source of energy is sunlight. Energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis. That energy then passes from organism to organism in food webs.

Ocean Literacy Standards met:

5. THE OCEAN SUPPORTS A GREAT DIVERSITY OF LIFE AND ECOSYSTEMS.

c. Some major groups are found exclusively in the ocean. The diversity of major groups of organisms is much greater in the ocean than on land.

g. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, methane cold seeps, and whale falls rely only on chemical energy and chemosynthetic organisms to support life.

Materials:

Scissors
Glue
Copies of Activity Sheet

Class time: 45minutes

Activity:

1. Have students list what they recall about photosynthesis (This exercise assumes that students have previously had a lesson on photosynthesis). Be sure that the discussion touches upon the conversion of sunlight to useable energy.
2. Tell students:
 - Most energy on earth originates from the sun.
 - Sunlight is converted by plants through the process of photosynthesis. Chlorophyll inside of the plant absorbs light energy and makes it usable for the plant. Carbon dioxide, water and sunlight are converted into sugar that plants then use for energy. This energy is subsequently passed through the food chain as other organisms eat the plants.

- Some organisms found in the deep sea and that students will be seeing at the *Beyond the Edge of the Sea* exhibit cannot draw energy from the sun and must find other energy sources to live.
 - These organisms get their energy not from the sun but from a process called chemosynthesis. This energy conversion happens at hydrothermal vents where bacteria convert carbon dioxide, water and hydrogen sulfide into sugar and sulfur compounds.
3. Pass out worksheet. Students will cut out sequence the steps involved in both photosynthesis and chemosynthesis.
 4. Upon completion of the worksheet activity provide students with the written equations for photosynthesis and chemosynthesis.
 - Photosynthesis:
Carbon dioxide + Water + Light Energy → Glucose + Oxygen. If your students are familiar with chemical formulas you can provide this version $6\text{CO}_2 + 6\text{H}_2\text{O} (+ \text{light energy}) \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$.
 - Chemosynthesis:
Carbon dioxide + Water + Hydrogen Sulfide → Glucose + Sulfur Compounds. Again if your students are familiar with chemical formulas you can show them this version $6\text{CO}_2 + 6\text{H}_2\text{O} + 3\text{H}_2\text{S} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 3\text{H}_2\text{SO}_4$. Be sure to tell students that this is just one possible equation for chemosynthesis. Carbon dioxide, water and glucose are always part of the equation but the hydrogen sulfide and sulfur compounds can be replaced by and iron ion and oxidized iron (rust).
 5. Ask students to look at the equations and ask for any observations that they make about them. They should notice that both equations require carbon dioxide and water but can vary in the energy source that it does not always need to be sunlight. They should also be able to see that one of the products in both equations is the sugar glucose, which provides energy; therefore even though the input is different as long as sucrose is produced there is a source of energy available that allows for life to be present.

Closing Discussion:

- The discovery of chemosynthetic communities was an important one in the scientific community. Why do you think this is?
- Can the same chemicals be put together over and over again to produce the same products?
- Do you think that chemosynthetic communities can found anywhere but the ocean floor?

Resources:

<http://www.pmel.noaa.gov/vents/nemo/explorer/concepts/chemosynthesis.html>

<http://www.divediscover.who.edu/vents/light.html>

<http://www.pmel.noaa.gov/vents/nemo1998/education/chemo.html>

<http://www.who.edu/oceanus/viewArticle.do?id=2505>

http://science.nasa.gov/headlines/y2001/ast13apr_1.htm

Name _____

Date _____

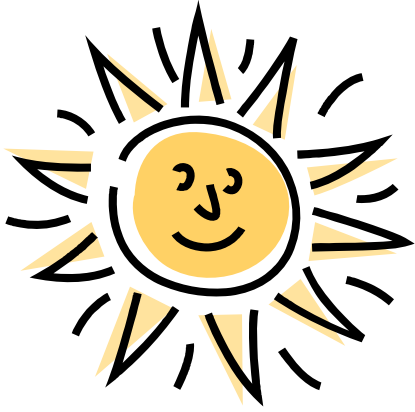
Cut out the images and place them in the correct order for each type of energy conversion.

Photosynthesis:

Step 1 Step 2 Step 3 Step 4

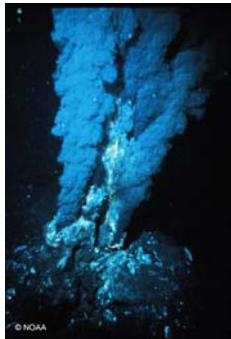
Chemosynthesis:

Step 1 Step 2 Step 3 Step 4



Chloroplast
(Find Image)

Bacteria
(Find Image)



<p style="text-align: center;">Humans</p> <p>Humans are the top of the food chain. We get energy from eating food like vegetables and meat.</p>	<p style="text-align: center;">Sun</p> <p>The sun provides energy to plants. This energy is converted and made into a sugar known as glucose.</p>
<p style="text-align: center;">Bacteria</p> <p>Bacteria found in the deep sea convert chemicals from the hydrothermal vents along with water and carbon dioxide into sugar.</p>	<p style="text-align: center;">Chloroplasts</p> <p>Chloroplasts are located within plant leaves. They absorb sunlight.</p>
<p style="text-align: center;">Fish</p> <p>Fish found in the deep sea feed on other vent organisms such as tubeworms.</p>	<p style="text-align: center;">Plant</p> <p>Plants convert sunlight, water and carbon dioxide into oxygen and sugar.</p>
<p style="text-align: center;">Tubeworm</p> <p>Are located in at hydrothermal vent sites. They have a symbiotic relationship with bacteria. The bacteria live in their gut and convert chemicals into food that the tubeworms can use.</p>	<p style="text-align: center;">Hydrothermal Vent</p> <p>Hydrothermal vents are found on the ocean floor near tectonic plate boundaries. Hot water extrudes from these vents with dissolved chemicals in the water.</p>

Beyond the Edge of the Sea Grades 6-8 Exhibit Activity

Title: “Back to the Drawing Board” Field Guide Illustrations.

Summary: Students will study one organism from the exhibit in depth and compare it to other similar species. Students will draw and make observations about the animal.

Background: Field guides provide a focused way to study and identify species using key characteristics. In 1934 the Rodger Tory Peterson published his first field guide *A Field Guide to the Birds*, since then illustrations have been used successfully to identify many species. Illustrations in these guides are able to capture and enhance descriptions of plants and animals more than a photograph can. Field guides as opposed to photographs let scientist add “field marks” that point out special features of each organism studied. The act of drawing itself serves to focus attention on the details and intricacies of each animal.

Objective: Students will learn how to use field guides as a scientific tool. They will draw and make detailed observations of deep sea chemosynthetic animals.

Grade level: 6-8

Subject areas: science and art.

Duration: 10-15 minutes, make sure to leave enough time for students to explore the exhibit on their own.

Setting: *Beyond the Edge of the Sea* exhibit space.

National Science Standards met:

CONTENT STANDARD G: HISTORY AND NATURE OF SCIENCE

- Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models. Although all scientific ideas are tentative and subject to change and improvement in principle, for most major ideas in science, there is much experimental and observational confirmation. Those ideas are not likely to change greatly in the future. Scientists do and have changed their ideas about nature when they encounter new experimental evidence that does not match their existing explanations.
- It is part of scientific inquiry to evaluate the results of scientific investigations, experiments, observations, theoretical models, and the explanations proposed by other scientists. Evaluation includes reviewing the experimental procedures, examining the evidence, identifying faulty reasoning, pointing out statements that go beyond the evidence, and suggesting alternative explanations for the same observations. Although scientists may disagree about explanations of phenomena, about interpretations of data, or about the value of rival theories, they do agree that

questioning, response to criticism, and open communication are integral to the process of science. As scientific knowledge evolves, major disagreements are eventually resolved through such interactions between scientists.

Ocean Literacy Standards met:

5. THE OCEAN SUPPORTS A GREAT DIVERSITY OF LIFE AND ECOSYSTEMS.

f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is “patchy”. Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.

7. THE OCEAN IS LARGELY UNEXPLORED

b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.

Materials:

Field Guide Template
Pencils/pen
Colored pencils
Clip board

Procedure:

1. Students will examine a Field Guide entry that examines characteristics of either shrimp, crabs and worms that are commonly found in the U.S.
2. After studying the guide entry, students will explore the exhibit and locate pictures and natural history brochures that provide information on the deep sea counterparts of the animal they have been assigned.
3. Students will use the template provided to make their own Field guide log entry. They will have to opportunity to draw and focus in on characteristics of the environments and adaptations and other organisms in the ecosystem of the organism they are investigating.

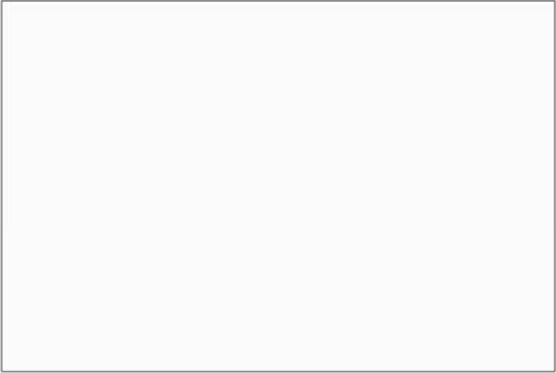
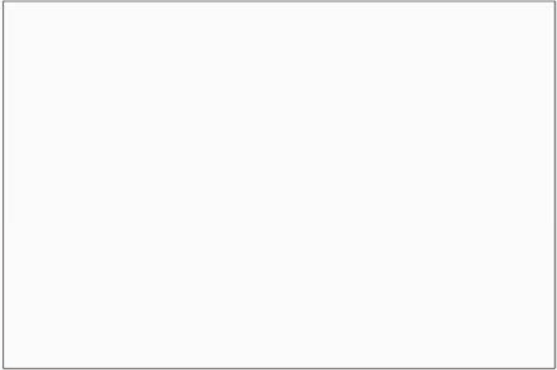
Resources:

Science

<http://www.sciencemag.org/cgi/content/full/293/5537/2002?ck=nck>

Article entitled Raising the Bar for Bird Guides. Though specifically on birds, this paper speaks to the importance and usefulness of field guide illustrations.

Example Field Guide Page: Atlantic Shrimp will be completed for students and serve as an example.

Atlantic Shrimp <i>Pandalus borealis</i>	Eyeless Shrimp <i>Rimicaris exoculata</i>
	
Habitat _____	Habitat _____
_____	_____
Color _____	Color _____
Shape _____	Shape _____
Special Markings _____	Special Markings _____
_____	_____
General Observations _____	General Observations _____
_____	_____

**Beyond the Edge of the Sea:
Grade 6-8 Post-Activity**

Title: “Meeting of the Mines”

Summary: Students role-play in a simulated town hall meeting on the issue of hydrothermal vent mining. This activity can follow up a visit to the *Beyond the Edge of the Sea* exhibit and serves as an extension of current events involving hydrothermal vent communities.

Background: Scientists and engineers speculate that the deep sea may contain an abundance of oil, gas, and mineral deposits. Gold, silver, copper and manganese have all been found at hydrothermal vent communities. With the demand for these metals on the rise, companies are looking to deep sea mining as a potential source to meet that demand. This poses many legal issues and will be a topic of debate in the coming years.

Objective: Students will learn scientific, environmental, political, and business perspectives on the issue of deep seabed mining through a town hall style discussion. They will explore debate and argue positions as they assume roles that may not necessarily correspond to personal beliefs.

Grade Level: 6-8

Subject areas: Social studies, current events, natural resource economics, physical oceanography, engineering and marine technology.

Duration: Variable – 30 minutes or longer. Background reading may be given as homework or allot extra time in longer classes.

Setting: Classroom (desks setup in a circle if possible).

Keywords: seabed mining, stakeholder, hydrothermal vents, deposits and ore.

National Standards met:

CONTENT STANDARD F: Science in Personal and Social Perspectives

- Causes of environmental degradation and resource depletion vary from region to region and from country to country.
- Societal challenges often inspire questions for scientific research, and social priorities often influence research priorities through the availability of funding for research.

Ocean Literacy Standards met:

1. THE EARTH HAS ONE BIG OCEAN WITH MANY FEATURES.
 - h. Although the ocean is large, it is finite and resources are limited.

5. THE OCEAN SUPPORTS A GREAT DIVERSITY OF LIFE AND ECOSYSTEMS.

c. Some major groups are found exclusively in the ocean. The diversity of major groups of organisms is much greater in the ocean than on land.

g. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, methane cold seeps, and whale falls rely only on chemical energy and chemosynthetic organisms to support life.

6. THE OCEAN AND HUMANS ARE INEXTRICABLY INTERCONNECTED.

b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.

e. Humans affect the ocean in a variety of ways. Laws, regulations and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (point source, non-point source, and noise pollution) and physical modifications (changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean.

7. THE OCEAN IS LARGELY UNEXPLORED.

c. Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.

Materials:

1. Copies of "Mine, All Mine" which can be accessed at <http://www.onearth.org/article/mine-all-mine>. Print enough for the entire class.
2. Stakeholder cards

Procedure:

Each group of students will take on the identity of a stakeholder group and prepare a position regarding vent mining. Each stakeholder group will work together in an effort to persuade opposing view points to vote in their favor.

1. Students read the article "Mine, All Mine" to get a sense of the issue. This may be assigned as homework or given 10-15 minutes at the start of class to complete. Have students answer these questions:
 - How do minerals accumulate on the sea floor?
 - Why do companies want to mine these resources?
 - What are some positive outcomes of mining underwater?
 - What are the negatives associated with mining underwater?

2. Break the class into 4 stakeholder groups below and hand them the accompanying scenario card.
 - Scientist
 - Mining Company
 - Environmental Activist
 - Tubeworm Spokesperson
3. In groups, students read their scenario card and discuss their position on deep sea vent mining. The goal is to convince members of the Town Hall meeting to vote for their view point. Students should then make notes supporting their argument using information from the article, scenario card, or what they learned at the *Beyond the Edge of the Sea* exhibit. If time allows students can do extra research about vent mining in preparation for the Town Hall Meeting. Make sure groups list at least three reasons for their position.
4. Each group of students needs to brainstorm possible arguments that will be made by other stakeholder groups and how they will respond. Groups also need to select one student to speak as a representative at the Town Hall Meeting.

Running the Town Hall Meeting:

1. Have students move desks into a large circle and place a name tag in front of them that identifies which stakeholder group they belong to.
2. Each group has 3-5 minutes to introduce themselves and their position on vent mining and their reasoning for opposing or supporting it.
3. After all stakeholder groups have presented there can be an Open Debate, this will last 5-7 minutes. This is a chance for students to bring arguments they have for or against mining. The teacher will choose only 2 students from different stakeholder groups to debate at a time.
4. Groups will then be given 30-45 seconds to present their closing remarks and try to sway the voters in their direction.
5. Have students vote about what should be done.

Closing Discussion or Homework:

Why do you think this issue is so controversial? Do you think that if more people knew about hydrothermal vents that mining would be a viable option for mining? Would you have voted differently than the stakeholder you represented? Why or why not?

Resources:

http://www.edf.org/documents/736_DeepSeaMining.pdf

<http://www.theworx.com/deepsea/mining.html>

<http://www.thenakedscientists.com/HTML/content/interviews/interview/649/>

<http://news.mongabay.com/2007/0517-png.html>

Stakeholder Scenario Cards

Tubeworm Spokesperson

As a tubeworm you are worried that your home will be destroyed and you will have nowhere else to go. You are a very specialized organism that lives at temperatures and depths only found at hydrothermal vents, if all vents are mined there will be no place for you to live. Vents are also important to you since you get energy from the chemosynthetic bacteria that are found there. You are also a sessile animal that cannot move like the crabs or shrimp that live near you. You would be unable to relocate if mining occurred at your vent. Many people are unaware of your existence as you were first discovered in 1977 and you don't think it is fair to destroy your population for mining purposes before you have been thoroughly studied.

Mining Company

You argue that the process of mining underwater is less energy intensive than on land. This is very important in a world that now faces the issue of global warming and is looking for ways to reduce carbon output. Mining metals at hydrothermal vent locations is necessary to sustain our way of life, as sources of metal on land are becoming depleted. Because the mining will no longer be occur on land less soil will be moved to access the metals, leading to less erosion and runoff resulting in less waste.

Environmental Activist

Right now very little is known about the deep ocean and there is the potential to learn much more, mining may limit scientific discoveries. You also think that there are just too many unknowns when it comes to the effects of mining hydrothermal vents. If mining occurs who knows what will happen to the communities that live. In all likelihood they will be smothered and die. Also, you think the money used to develop technology to mine vents should instead be used to focus on recycling the metal we already have or in developing new technology that does not require metal. You also realize that the know one owns the sea floor, which means it belongs to all of us and it should not be used to benefit the bottom line of mining companies.

Scientist

You are in an interesting position. You want to study hydrothermal vent sites to learn more about their biology, ecology and geology, however, you require funding for your research. Sometimes mining companies are the ones that provide the money for your studies. If someday vents are mined you want to be in good standing with the mining companies so that you can oversee that process and make sure it is being completed in an environmentally friendly way.