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The Changing Climate of Science Education: Bringing Ocean Acidification to Middle School Teachers

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Author
Gottlieb, Emily

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The Changing Climate of Science Education: Bringing Ocean Acidification to Middle School Teachers

Emily Gottlieb
2013 MAS MBC
Scripps Institution of Oceanography

Advisors:
Andreas Andersson, Kristin Evans, David Kline
Introduction .............................................................................................................................................. 2

The Environment of Science Education: ................................................................................................. 3
Science Curriculum Standards .................................................................................................................. 3
STEM to STEAM ....................................................................................................................................... 4
Funding for Educational Outreach ........................................................................................................ 5
Climate Change and Environmental Science Education Research ...................................................... 5
Obstacles .................................................................................................................................................. 6
Monitoring and Assessment .................................................................................................................... 7
Place-Based Environmental Education Research .................................................................................... 8
Interdisciplinary Collaboration ................................................................................................................ 10
Teacher Training Research ..................................................................................................................... 10
Teacher Educators ................................................................................................................................ 11
Teacher Training Workshops ................................................................................................................. 12
Promoting Scientific Inquiry .................................................................................................................. 12
Scientist-Classroom Partnerships .......................................................................................................... 13
Ocean Acidification Workshop ............................................................................................................... 15

Background and Existent OA Lesson Plans .......................................................................................... 15
Outreach and Participation ....................................................................................................................... 17
Workshop Day ........................................................................................................................................ 18
  Summary of Lessons for Future Workshops ....................................................................................... 21
Garnering Feedback ............................................................................................................................... 21
  Summary of Suggestions for Garnering Feedback .............................................................................. 23
OA Exploration Feedback ....................................................................................................................... 23
  Summary of Participants’ Feedback: ..................................................................................................... 27
Discussion ............................................................................................................................................... 28

Avenues for Future Research and Work ................................................................................................ 28
Conclusion .............................................................................................................................................. 30

Bibliography ........................................................................................................................................... 31

Appendix ................................................................................................................................................. 35

Workshop Flyer ....................................................................................................................................... 35
OA Explorations ...................................................................................................................................... 36
Literature Activity .................................................................................................................................... 45
OA Background Presentation ................................................................................................................. 48
Workshop Feedback .............................................................................................................................. 51
OA Exploration Feedback ....................................................................................................................... 53
Introduction

Our changing climate demands changes in public education. Middle school science classrooms are on the precipice of a great transition as recently published national science education standards are calling for the integration of climate change into their curricula. These changes present great opportunities for innovations in the structure of middle school science lessons and equally great challenges for middle school teachers who will be faced with the task of disseminating the complex and nuanced topic of climate change in a way that will engage their students.

I designed a professional development workshop for middle school teachers on the topic of ocean acidification. Ocean acidification, a clear and measurable change happening in the ocean, can be directly linked to human activities like burning fossil fuels. Teaching about changes, like ocean acidification, that are happening to the charismatic, curiosity inspiring ocean, may be an effective way to engage a young audience in the topic of climate change. I chose to create this workshop for teachers because of the broad impact that teachers can have on all of their students and on the schools where they work. The workshop was developed mindful of the current and emerging advances in science education and education research. The workshop was designed firstly to provide educators with the tools and resources to teach about ocean acidification and secondly to begin to answer questions about how to effectively educate teachers about teaching climate change. Furthermore, this project may serve as a model for potential future integration of climate science research and public education.
The Environment of Science Education:

Science Curriculum Standards

Current developments in national science education standards call for the introduction of climate change and related topics as early as middle school (Gillis 2013, Achieve 2013). Teachers will need to adapt their pedagogy and learn new scientific material to meet these new standards with their classrooms. Integrating ocean science into lesson plans may be one way to engage middle school students with the topic of climate change.

The Next Generation Science Standards (NGSS) were published in April 2013. These are the first national science education standards to be published since 1996, and they were written by a 26-state consortium and a staff of 40 writers. They were written based on the 2011 National Research Council report A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (Achieve 2013). The NGSS stipulate that middle school life sciences should educate students about “interdependent relationships in ecosystems” (Achieve 2013). According to the performance expectations included in the NGSS, students will understand interactions between organisms and the abiotic environment. Students will be able to explain ecosystems and the scientific, political, and social tools used to manage them. Middle school earth and space sciences will cover “human impacts” so that students will understand the impacts that humans have on the earth particularly through development and the use of natural resources (Achieve 2013). These standards seek to develop students’ skills to critically evaluate scientific evidence of climate change (Gillis 2013).

States may use the national standards to create their own science education standards on a voluntary basis. Where states choose to introduce climate change into middle school science curriculum, teachers may benefit from training workshops to develop effective ways to engage their young audiences with the complex and nuanced subject.
**STEM to STEAM**

The STEM to STEAM movement is a national dialog that has been sparked regarding the integration of arts into the traditional science, technology, engineering and math (STEM) disciplines. Art may be a meaningful way to inspire and maintain student’s interest in the STEM subjects, and could be a useful tool to explore the topic of climate change with middle school students.

Dr. Judith Ramsey coined the term STEM in 2004 while she was assistant director of the education and human resources directorate at the National Science Foundation (NSF) (Gulo 2011). In 2010, Harvey White, co-founder of Qualcomm Inc. and Leap Wireless International Inc. coined the phrase STEAM (Gulo 2011). STEAM incubators, camps, and academies are cropping up around the country. They are spaces where art is integrated into the STEM disciplines (Dail 2013, Eger 2013). The NSF is funding a project called “The Art of Science Learning” to explore some ways that artistic thinking can be used to address problems traditionally addressed by the STEM disciplines (Art of Science Learning 2013).

Convergent thinking in traditional STEM disciplines does not allow for multidisciplinary solutions to complex problems like climate change (Kawasaki 2013). Middle school classrooms could be an ideal place to introduce practices of divergent thinking. For instance students may be asked to write about, draw, or act out creative solutions to global climate change problems. Such exercises can enhance the type of thinking skills necessary to tackle problems that span across multiple disciplines. Practicing this kind of social and cultural innovation with students may encourage them to envision ways to fill the need for the integration of new technology, like alternative energy sources, into society (Malina 2013).

The lesson plan that I developed for middle school students on the topic of ocean acidification (see Appendix: Ocean Acidification Workshop) has great potential for the integration of art. One of the teachers who attended the ocean acidification workshop even developed a literature exercise for her class based on the information from the workshop (see Appendix: Literature Activity).
Funding for Educational Outreach

There is a call from science funding sources, like the NSF, for researchers to incorporate educational outreach into their work. This provides a great opportunity to integrate current climate research and public education.

One of the goals from the NSF strategic plan is to “expand the scientific literacy of all citizens” (NSF 2006). Research proposals submitted to the NSF are evaluated based on their intellectual merit and the broader impact that the proposed activities will have on society (NSF 2007). Research proposals may include plans to integrate research activities into STEM teaching and the professional development of K-12 educators in order to meet these “broader impact” requirements (NSF 2007).

Integrating current climate research into middle school science curriculum and fostering partnerships between researchers and classrooms could enhance public education. Writing science lessons that accurately portray and even incorporate scientific data and methods might be a powerful way to engage students with climate change and science in general. Given the NSF broader impacts requirements for research proposals, this kind of integration could be the future of science education.

Climate Change and Environmental Science Education Research

“Environmental education can be seen as the bridge between science education and social responsibility and is considered as one of the most important factors for preventing environmental problems.” (Özden 2008)

I developed the ocean acidification explorations, introduced them to middle school teachers and gathered their feedback on the explorations to begin to explore effective methods of introducing climate change into middle school classrooms. The potential incorporation of climate change into middle school science demands and provides opportunities for education research. Education research can help to develop methods for analyzing the implementation of climate change interventions, which are plans to teach the academic and social tools that students need to fully understand the topic, and to conduct said analysis in order to improve methods of implementation. This section will summarize some science education research that has begun to look at the
challenges and successes of teaching climate change.

Obstacles

Climate change can evoke strong emotional reactions in people and it is a vast and topic. Its emotional implications and magnitude make it a very challenging topic to teach, particularly to middle school students.

Pessimism is a common emotional response to environmental problems (Hicks 2007). Denial can also be a response to a threat that is perceived as uncontrollable (Lazarus 2009). Education about global issues can sometimes exacerbate negative feelings (Hicks 2001). Negative emotions about climate change, like helplessness and anger, can impact an educator’s belief in climate change (Lombardi 2013) and/or his or her ability to effectively teach about the topic. Teachers’ emotional projections on the subject of climate change can shape their students’ emotional reactions and this can impact whether students effectively grasp the subject matter (Ojala 2012). An individual’s belief in the efficacy of their own actions may influence their attitude towards climate change and mitigation (Gifford 2011). Enabling people to deal with worry constructively without downplaying the magnitude and severity of environmental problems can be a difficult balance to strike. Hope can act as a strong motivational force, if denialism can be controlled for (Ojala 2012). One study found that infusing ‘constructive hope’ into lessons about climate change had a positive influence on students’ pro-environmental behavior (Ojala 2012).

Professional development courses in the future might be aimed at drawing awareness to teacher’s emotional reactions to climate change so that they can become more conscious of the ways that their emotions and preconceptions about climate change might be affecting their ability to teach the subject (Lombardi 2013). Also, professional development for teachers, with lessons on how to effectively communicate hope with regard to climate change while still presenting the subject matter honestly (i.e. avoiding denialism) might prove effective in not only conveying climate change to students but in promoting pro-environmental behavior.

Groups like the IUCN have taken this lesson of using hope to develop their “Love not Loss” campaign, which guides communicators of climate change to focus on the
positive elements of the environment rather than losses due to human activity (IUCN 2013). A message like “love not loss”, conveyed specifically to teachers through professional development, might have a great impact on their efficacy in teaching about climate change.

The complex and interdisciplinary nature of climate change is another challenge to teaching the topic to middle school students. Understanding climate change requires understanding the multiple disciplines that are invoked. Even educators with backgrounds in life or atmospheric sciences might not be up to date on the latest research and findings in these fields. Educational liaisons may foster ongoing relationships between researchers and educators, giving teachers access to experts who can help them to understand and teach the complex subject.

**Monitoring and Assessment**

This section outlines some existing methods for garnering information about students’ and teachers’ baseline understanding of and attitudes towards climate change and science in general, efforts to analyze science curriculum in schools, and how these tools can be used to create and implement climate change interventions.

Environmental knowledge surveys provide information about public understanding of key environmental issues (Robelia 2012). The use and analysis of these surveys could establish the baseline climate change knowledge of middle school students and teachers and could measure changes in relevant attitudes and behavior with the introduction of new curricula.

An instrument for measuring science attitudes is the Test of Science Related Attitudes (TOSRA) (Fraser 1981). TOSRA identifies and tests seven distinct science related attitudes in secondary school students; social implications of science, normality of scientists, attitude of inquiry, adoption of scientific attitudes, enjoyment of science lessons, leisure interest in science and career interest in science (Dijkstra 2012). Future science education research could use this rubric to evaluate changes in science attitudes in classrooms where climate change curriculum has been introduced under different scenarios (i.e. after teacher training on emotional awareness of teaching climate change or with the development of researcher-educator or researcher-
classroom collaboration).

Project 2061 curriculum analysis is a research project funded by AAAS to improve science and math curriculum. The project has developed and field-tested an analysis of curricula based on how well they help students to achieve benchmarks and standards (Stern 2002). The idea behind the project is to move public school standardized test taking closer to its purported goal of improving the system of education and away from the tendency for test-taking to become and end in itself. This idea could be applied to testing the effectiveness of climate change curriculum on students’ ability to meet the new climate change benchmarks and standards. This could provide a useful tool in developing effective new curriculum.

The NSF has called for studies that examine how interventions are introduced into schools, once introduced how they are sustained, and what organizational elements in the schools lead to successful integration of new interventions (Robelia 2012). Such implementation research could illuminate the characteristics that make for successful, sustainable, and widely adoptable interventions. Such research could also identify best practices and characteristics of schools that successfully adopt new intervention to serve as examples for schools that might be struggling (Robelia 2012).

If curriculum analysis could be designed to look beyond benchmarks and standards to evaluate the effectiveness of climate change curriculum on student’s attitudes and behavior, this science education research could have even wider reaching social implications for communication and activism towards climate change resilience.

**Place-Based Environmental Education Research**

Place-based environmental education research, which looks at the intersection between environment, psychology, and learning, could be combined with classroom science education research to improve understanding and practice of climate change education.

Research on the psychology of learning and environmental psychology can be used to develop theories and practices in climate change education. Interactional theory is an environmental-psychological theory that individuals derive specific outcomes from interacting with different components of their environment (Brownlee 2013). Based on
this theory, an important part of learning about climate change, and one that may not be replicable in the classroom, might be direct interaction between students and their natural environment, or place-based learning. Environmental education researchers can use this theory to explore the educational significance of physical experiences in nature (Brownlee 2013).

The theory of “place bonding” suggests that individuals can form powerful psychological bonds with natural resource settings (Brownlee 2013). For example, the “OA explorations”, described later in this paper, could be extended to include the incorporation of real time data from the Sea Water Acidity Monitoring Project (SWAMP) program off of the Scripps pier in La Jolla. If this were to happen, it might be beneficial for classes to come visit the pier and/or to take water samples in La Jolla the tide pools. A supplemental field trip like this could help students to form a bond with the place where ocean acidification is being monitored. That psychological bond might make related activities in the classroom more meaningful and effective.

Personal experiences with natural resources and settings that stand to be affected by climate change might overcome some of the barriers to teaching about climate change such as mistrust of science, negative emotions associated with climate change, denialism, a sense of powerlessness in the face of a global environmental problem. In one study, hands on experiences with sea animals were found to impart positive psychological effects like positive moods, environmental sensitivity and affective learning (Zeppel 2008). These personal experiences can be fostered in students through environmental and place-based education. Further research regarding the psychological links between these experiences and attitudes towards climate change could be useful in developing place-based climate change lessons to supplement classroom curricula.

While some studies have been done to evaluate the education and conservation benefits of direct wildlife experiences (Zeppel 2008), there are still avenues of exploration remaining for research. For instance, what kinds of direct experiences with the environment have education and conservation benefits with regards to teaching and enacting behavioral changes related to climate change. In other words how do you provide impactful experiences with natural settings that stand to be indirectly affected by
human activities? Will such experiences be helpful in teaching climate change? Additionally, what are ways to provide these direct environmental experiences, assuming that they do have educational and conservation benefits relating to climate change, when there are economic or logistical barriers preventing students from having typified experiences with natural resources (i.e. inner-city, low income schools)? Equitable access to learning enhancing experiences in the outdoors is an important issue of educational policy, which could be informed by more research on the efficacy of place-based education.

**Interdisciplinary Collaboration**

Interdisciplinary collaboration between educators could be a key factor to developing effective methods of teaching climate change to middle school students. I touched briefly on the STEM to STEAM movement and some of the implications that this would have for incorporating more interdisciplinary collaboration into public schools. Further, at a university in Australia, a teacher network was formed to promote interdisciplinary climate change education. One study that looked at this teacher network, outlined some obstacles to this type of interdisciplinary collaboration, which might be relevant at the middle school level. This study called for a need for more recognition of the benefits of interdisciplinary learning as well as financial and resource support for teacher collaboration (Pharo 2012). Experiments in the practice of interdisciplinary education in middle schools, particularly with regard to teaching climate change, could help to identify specific institutional needs in order to accomplish successful collaboration and learning goals.

**Teacher Training Research**

“Teachers are key players in the renewal of science education” (European Commission 2007)

In undertaking the ocean acidification workshop for middle school teachers, I was introduced to the challenges and rewards of teacher training. I chose to target teachers with my project because of the incredible ripple effect that teachers may have on all of
the students who they reach during their careers and the educational infrastructure of the schools in which they work. The field of teacher education is one that has been little studied but one which is coming to prominence.

Science teachers are faced with the task of conveying increasingly complex subject matter to increasingly complex classrooms. Teacher educators play an essential role in preparing teachers for the demanding task that they must fill in the changing climate of education. Teaching climate change poses additional challenge for teachers and an additional opportunity for teacher educators and research on teacher education.

Research is starting to address some of the questions about teacher education that could improve the field. Research has begun to illuminate the pedagogy and experience that teacher educators are bringing into their training. Further research has and should continue to look at the objectives of teacher training workshops, specifically with regard to promoting scientific inquiry teaching. Such research on teacher educators and teacher training workshops can help to identify best practices to improve efficacy and science education outcomes.

**Teacher Educators**

One study on teacher educators revealed some effective practices of science teacher educators. One of the important roles that teacher educators play is enabling teachers to see subject matter from the perspective of the learner, a practice that can give them insight to improve their own teaching methods (Berry 2013). Effective science teacher educators should also be explicit with their teacher-students about the “problematic nature of science”, the nuances, and the difficulties to teaching and learning different subjects (Berry 2013). Such discussions can shed light on the most challenging aspects of teaching science and such awareness might lead to improved pedagogy of difficult subject matter. Teacher trainers also serve to teach educators ways to teach science in a way that is more engaging and motivating to their students (Berry 2013). More research and shared knowledge between teacher educators about their methods of teaching teachers could improve the practice of science teacher education (Smith 2000).
Teacher Training Workshops

One study began to illustrate how early teachers can develop meta-cognitive awareness of their own learning in science and how this awareness can help them to form their own science pedagogy and to more effectively interpret science curricula in their classrooms (Parker 2013). Teacher training workshop environments can be places where this kind of reflection is fostered and explored in an organized manner. There is a need for further research on how new teachers develop their understanding and relationship to science curriculum content and how metacognition of their learning of this content could impact their efficacy as teachers (Parker 2013).

Furthermore, teacher training workshops can provide places where teachers can practice their own explanations and understanding of counterintuitive science phenomenon before they attempt to teach and explain these phenomena in their classrooms (Parker 2013). For instance, during the demonstration of the “OA explorations” in the workshop (see Workshop section), the workshop participants added put an egg into vinegar, as part of one of the lessons, and bubbles were produced. Participants predicted that these bubbles would be full of carbon dioxide and that the dissolution of this carbon dioxide would, over time, decrease the pH of the liquid. Instead the pH of the liquid increased over time. An ocean acidification researcher, who participated in the workshop, explained that this confusing phenomenon was due to the complex nature of calcium carbonate dissolution. It was helpful for the participants to experience the counterintuitive results of the lesson in the workshop, where they were able to ask questions and gain clarification, before taking the lesson into their classrooms.

Promoting Scientific Inquiry

Teaching scientific inquiry is one of the challenges and keystones in science education. According to the National Science Education Standards, a mastery of scientific inquiry is characterized by the following:

“Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light
of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results (National Research Council 1996).”

Teachers, like students, need guidance to fully understand, and teach scientific inquiry. Teacher training to improve methods of teaching scientific inquiry could improve student learning (Grigg 2013). Further study to understand the specific impacts and effective methods of teacher training on the expected outcomes of scientific inquiry in students would be useful in identifying methods to better teach teachers how to teach scientific inquiry. Beyond this, research that looks into how each feature of scientific inquiry relates to student achievements in science and attitudes towards science could further refine the definition of scientific inquiry (Grigg 2013).

In one study, experienced teachers advised new teachers about how to implement inquiry-based science teaching. The experienced teachers advised the novices to watch demonstrations of inquiry learning from other teachers, to engage in inquiry activities themselves, and to read literature about inquiry teaching. The goal of the study was for new teachers to effectively construct their own theories of inquiry and inquiry teaching (Tseng 2013). According to the study, teacher educators should contrast well-structured and ill-structured inquiry lessons in demonstrations. Teacher educator demonstrations of inquiry teaching can come from examples from experienced teachers and should display a variety of inquiry teaching techniques and practices. Further, teacher educators should encourage teachers to reflect on their own beliefs and practices of inquiry teaching and should encourage ongoing teacher community support for inquiry teaching (Tseng 2013). If these efforts to teach teachers inquiry-teaching were documented and measured, they could be effectively developed into teacher education material, implemented, and adapted for a variety of teacher audiences.

**Scientist-Classroom Partnerships**

Partnerships between science researchers and classrooms have great potential to improve science education. More application and study of these partnerships could help to create models for successful science programs in the future.
There are several models of school-science partnerships and teacher-scientist partnerships. These partnerships have the potential to reframe science classes and science pedagogy so that they integrate with current science research. Such partnerships could be a powerful tool for middle school educators beginning to integrate climate change into their classrooms. This change in curricula might be an ideal platform for a change in the structure of science classes in general.

One model of a school science partnership called Forests-of-Life, attempted to change one school’s science classes from the standard short module to lengthy interdisciplinary modules, spanning multiple terms. Forests-of-Life was designed so that classrooms and scientists could work together on local research projects (Falloon 2013). The program had successes and provided lessons for future programs. Some of the problems that the program ran into were related to the difficulty of bridging the gap between the teacher’s pre-existing knowledge plus the infrastructure of the school and the methodology and subject matter that the scientists were trying to impart (Falloon 2013). For example, scientist/teacher collaboration and a stepwise plan could, in the future, help to implement a similar program designed to bring local ocean acidification research, like the SWAMP research, into San Diego classrooms and to transform the way that science classes are structured and taught.

Furthermore, when teachers become directly involved in research, their ability to teach science and their students interest in the science topics may improve. ARISE (ADRILL (Antarctic Geological Drilling) Research Immersion for Science Educators) engages teachers in all aspects of science research from the field research to the discussion of scientific results (Cattadori 2011). Scientists and educators work together to develop educational material. Additionally scientists engage in ongoing communication with the teachers and their schools. A network of communication between participating educators is maintained through blog posts, emails, meeting, videoconferences, and refresher courses for teachers. The ARISE program has been successful in retaining participating schools and in producing final projects with schools (Cattadori 2011). It would be interesting to apply this same model of teacher research immersion and test it using TOSRA and curriculum analysis to see if this type of teacher training has a measurable positive impact on students science comprehension and
attitudes. A similar program could be designed engaging local middle school teachers and classrooms with climate related oceanography research at Scripps Institution of Oceanography.

Ocean Acidification Workshop

Background and Existent OA Lesson Plans

The OA exploration workshop was designed with two objectives in mind. The first was to provide middle school teachers with the tools and knowledge to bring a new topic of marine science research, which is closely linked to climate change, into their classrooms. The second was to analyze and reflect upon the workshop and the subsequent integration of the lesson material into the classrooms. The product of the latter objective will be information and insight to improve upon methods of introducing current climate change research topics into middle school classrooms through teacher training workshops in the future.

To develop the material of the workshop, I consulted the wealth of existent ocean acidification lesson plans that have been developed by researchers and educators. Educational outreach material about ocean acidification is available online and ranges from short demonstrations to long-term experiments to conduct with classrooms. The following is a summary of the educational material that I found to be helpful in developing my “OA explorations”. These could be useful for instructors hoping to incorporate this topic into their science and climate change curriculum.

I created my OA explorations mainly by adapting Sarah Cooley’s “Ocean Acidification Lab” for grades 5-12 (Cooley 2009). This lesson plan includes a table with the pH of various common liquids. It also includes a section where students test the alkalinity (i.e., the acid neutralization or buffer capacity) of different liquids using aquarium alkalinity test strips. This lesson plan includes questions for each of the three sections and a teacher’s answer key. The Birch Aquarium has developed a “Climate Challenge” for grade levels 7-12 in which students observe a greenhouse gas demonstration, an ocean acidification demonstration, and then work to estimate their own carbon footprint (Birch 2012). The program was designed as a compliment to the
Aquarium’s “feeling the heat exhibit”. Bill Andrake’s “Coral Reefs in Danger: Ocean Acidification Lesson” is designed for 6-8th graders and takes students through a series of ocean acidification lessons where each component is explained with chemical equations (Andrake ND). The lesson plan also includes question sheets, links to supplementary resources, and an exercise incorporating data from A Long-Term Oligotrophic Habitat Assessment (ALOHA) station where they have been collecting long-term open ocean acidification data. NOAA’s office of national marine sanctuaries education department created a lesson plan called “Marine Osteoporosis” for grade levels 5-8 exploring the dissolution of calcium carbonate in water with vinegar (NOAA 2010). The lesson plan also includes additional websites and resources. Center for Ocean Sciences Education Excellence (COSEE) West developed “Shells and the Impact of Ocean Acidification” in which students put liquids with a range of pH onto eggshells and predict which ones will react with the shells (COSEE 2012). The lesson plan also provides brief ocean acidification background for teachers and students and additional resources. The Center for Microbial Oceanography: Research and Education (C-MORE) designed a comprehensive OA lesson plan for 6-12th grade students that includes a narrated PowerPoint and a DVD of a lesson plan (C-MORE ND). The Bermuda Institute of Ocean Sciences (BIOS) Ocean Academy “You be the Chemist: Ocean Acidification” lesson plan is designed for 3rd through 8th graders (BIOS 2013). It includes a good review of the global carbon cycle with diagrams. In the lesson, students count hatching artemia (sea monkeys) to explore the affects of ocean acidification on marine organisms. The lesson also includes links to real-time ocean acidification data and additional resources.

Instead of creating an entirely new lesson plan, I synthesized existent educational material into a series of “explorations” created specifically for middle school students. The OA explorations take classrooms through exercises and discussions to build an incremental understanding of ocean acidification. There were four “OA explorations”. In “OA Exploration Part 1: Is the pH of Seawater More Like Vinegar or Soap?” students are introduced to pH and pH indicator made from cabbage juice. They explore the range of pH of household items and compare them to the pH of seawater. “OA Exploration Part 2: How Does Seawater Resist Changes in pH?” is an introduction
to the buffering capacity of seawater. Students will observe how seawater resists changes to pH differently than fresh water by blowing carbon dioxide into both and observing the relative changes in pH. In this part, the class will discuss how and why dissolving carbon dioxide decreases water’s pH. “OA Exploration Part 3: How Will Marine Animals With Shells Respond to Changes in Seawater’s pH?” takes place over two days. Students predict and then observe what happens to an eggshell left in vinegar overnight. In this part, the class will discuss the similarity between the material of eggshells and that of calcifying marine organisms. They will discuss how some marine organisms will be affected negatively by ocean acidification. “OA Exploration Part 4: Adjust or Go Extinct!” is a quick exercise in which the class plays out what might happen to the marine food web if some calcifying species are negatively impacted or lost due to ocean acidification.

My aim in writing the “OA explorations” was to produce the necessary guides, resources, and activities for educators to incorporate ocean acidification into broader lesson plans of their own design.

**Outreach and Participation**

The first step after conceiving of the workshop and writing the explorations was to find teachers to participate in the workshop. I created a flyer advertising the workshop which included information, about the lessons that participants would receive to bring back to their classrooms and about the additional activities that they would participate in during the day including a free access to the Birch Aquarium, Lunch, a tour of a Scripps Research lab, and a visit to the Scripps pier (See Appendix: Workshop Flyer). I sent out this flyer by emailing administrators of listserves for local educators. Future workshops may benefit from promoting on the following listserves:

<table>
<thead>
<tr>
<th>List Serve Name</th>
<th>Administrator</th>
<th>Contact</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Diego Education Association</td>
<td>Jonathan Mello</td>
<td><a href="mailto:mello_j@sdea.net">mello_j@sdea.net</a></td>
</tr>
<tr>
<td>Teachworth List</td>
<td>Martin Teachworth</td>
<td><a href="mailto:mdeachworth@sbcglobal.net">mdeachworth@sbcglobal.net</a></td>
</tr>
<tr>
<td>KidsEcoClub</td>
<td>Susan Guinn</td>
<td><a href="mailto:sguin1@san.rr.com">sguin1@san.rr.com</a></td>
</tr>
<tr>
<td>The San Diego Science Alliance</td>
<td>Nancy Taylor</td>
<td><a href="mailto:nancy.taylor@sdsa.org">nancy.taylor@sdsa.org</a></td>
</tr>
<tr>
<td>OceanList</td>
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<td><a href="mailto:oceanlist@lists.ucla.edu">oceanlist@lists.ucla.edu</a></td>
</tr>
</tbody>
</table>
I also emailed the flyer to administrative staff and principals from the San Diego Unified School Districts’ list of middle schools. This was time consuming and it is difficult to determine how many of the workshop participants found out about the workshop because of this effort.

One workshop participant reported finding out about the workshop through Martin Teachworth’s listserve. Another participant, who is a school-based initiative discovery fellow at the Ocean Discovery Institute, found out through her organization following a meeting that I had with their associate director and school programs manager. One participant found out by an email sent from his principal, but it is unclear whether that email came about as a result of my direct contact with the principal or whether the principal found out about the workshop from one of the listserves. Future educational workshops should survey their participants to learn how they found out about the workshop. This can inform methods for future workshop hosts to effectively promote their workshop.

**Workshop Day**

The workshop was held on Saturday March 30th. The day was broken up into two parts. First, I met the six workshop participants at the Birch Aquarium. In a classroom at the aquarium, I gave a background lecture about ocean acidification (See Appendix: OA Background Presentation). The presentation was punctuated by questions. Some participants had a better grasp of the chemistry and biology concepts than others. One participant in particular was rather quiet throughout the presentation and may have been struggling to follow some of the content. Mindful of the participants’ varying levels of comfort with the subject matter, teacher trainers in the future should make an effort to explain concepts and terms simply at first, to “get everyone on the same page” before building complexity. For instance before using the term “anthropogenic carbon emissions” it might be helpful to start with a definition like, “human activities that burn fossil fuels and put carbon dioxide into the atmosphere” and then give examples such as driving cars and deforestation.

Some of the questions that the teachers had were beyond my scope of
knowledge. I asked the teachers to remember these questions to ask Andreas Andersson, the ocean acidification researcher who served as an advisor for this project and whose lab we would visit during the second part of the day. It is important for the teacher trainer to accurately and honesty portray his or her own background and level of knowledge on the topic being presented. It is also helpful to have the support of experts whom participants can contact with more in depth questions about complicated research topics.

Following the presentation, I set up for the Ocean Acidification exploration demonstrations. I demonstrated the “OA Exploration” parts one, two, and three with the teachers (See Appendix: OA Explorations). These demonstrations were an important part of the workshop because they allowed the participants to observe and practice the execution of the lessons. We were able to discuss, as a group, which elements would be difficult to preform and what parts might not go as planned or might provide confusing results when conducted with a class. For instance, when conducting “OA exploration, part two: How does seawater resist changes in pH”, we took two cups, one filled with tap water, and one filled with seawater, and added a cabbage juice pH indicator to both. We then blew into the cups with straws to see how the rate of the two liquid’s pH change differed with the addition of carbon dioxide. The difference in color between the seawater and the tap water with the cabbage juice indicator was subtle, and the rate of change in color as we blew into the cups was difficult to see. This led to a discussion of using universal indicator instead of, or pH strips in addition to, the cabbage juice pH indicator in order to get a more drastic and more accurate indication of the changes in pH.

During this first part of the day, it was helpful to have extra people assisting with the workshop. Frances Kinney took photographs of the workshop and Kristin Evans provided an extra pair of hands during the demonstrations. Kristin also observed the entire workshop and provided invaluable insight throughout the day and feedback afterwards. Teacher trainers in the future should think about how many people they will need in order to help with the workshop and may consider having a non-participating education expert sit in on the workshop to provide unbiased feedback.

Following the demonstration of the OA explorations, the participants toured the
Birch Aquarium and then I provided them with lunch. The lunch break was a nice time for the participants to talk and get to know each other, to ask questions about the workshop, and for me to get to know a little more about their backgrounds. Establishing a rapport with the participants was helpful later when it came time to getting feedback from them. As I will discuss in the following section, getting the participants to fill out surveys after the workshop was a challenge and required me to email them frequently. I think that getting to know them a little bit during the workshop and particularly in the downtime at the lunch break, made the future correspondences easier and made them more willing to help out my project by filling out the surveys.

Two graduate students, Molly Gleason and Susan Kram from Jen Smith’s lab, joined us for lunch and accompanied us to Andreas Andersson’s lab. Andreas met us there with another graduate student, Kylie Yeakel. Andreas and Kylie performed a demonstration using a candle floating on water with pH indicator in it to show how carbon dioxide affects pH of the top layer of a body of water in a closed system. Then they talked to the participants about their research using long-term, open ocean monitoring of ocean acidification. They spent time answering questions about ocean acidification, some of which the workshop participants had collected during the morning portion of the workshop. Then, Susan and Molly took the participants on a tour of the neighboring Smith lab, and discussed ocean acidification research that they are doing in the highly variable near shore environment. They accompanied the participants out to the Scripps pier where they were able to see the equipment that the researchers are using for the SWAMP research.

Having a researcher like Andreas and graduate students, involved in the workshop was important for many reasons. Andreas acted as an advisor throughout the project so he was able to oversee the content of the presentation and the OA explorations to ensure their scientific accuracy, in addition to answering dozens of questions on the day of the workshop. Having the graduate students involved was important because they are active learners like the workshop participants themselves, and like the students that the participants will bring their lessons back to. Their insight and perspective on the topic helped the workshop participants to gain a deeper understanding of ocean acidification.
The tour out to the pier, in addition to being a draw for people to attend the workshop, served to tie the OA explorations into real time local research. This link between public school classrooms and real time local data could be fostered further in the future. The Education and Research: Testing Hypothesis (EARTH) program at the Monterey Bay Research Institute has been conducting curriculum development research using near real time climate data as learning tools in classrooms (EARTH 2013). As more such data becomes more readily available to the public, it would be ideal material for classrooms to explore the analysis of data sets and the variability of real time data that relates to climate change.

**Summary of Lessons for Future Workshops**

- Advertise for workshop by contacting administrators of list serves for local educators, administrative staff, and school principals
- Survey participants about how they found out about workshop
- Be mindful of participants varied educational background and familiarity with subject matter in presentation (e.g. explain concepts and terms simply at first, to “get everyone on the same page” before building complexity)
- Accurately portray teacher trainer’s background and level of knowledge
- Have the support of experts as contacts for the participants
- Use lesson demonstrations
- Consider how many people are needed to assist in the workshop
- Have non-participating education expert sit in and provide feedback
- Allow for time to talk informally with participants
- Have researchers/graduate students participate
- Tie workshop topic into real-time and/or local data

**Garnering Feedback**

Getting feedback from the participants after the workshop was an unanticipated challenge and one that produced lessons from which future teacher trainer might benefit greatly.

I created two surveys for the workshop participants to fill out using the website
SurveyMonkey. The first survey, entitled “OA workshop feedback” was sent out to participants on April 3rd, four days after the workshop. The survey consisted of five questions, three of which asked them to rate different components of the workshop in a rubric, and the remaining two of which were multiple choice and relating to the participants plans to use the OA explorations with their classrooms and willingness to participate in similar workshops in the future (see Appendix: Workshop Feedback). Only three of the six workshop participants completed this first survey. I would suggest that a quick survey like this be given in paper form to the participants at the end of a workshop to ensure feedback.

The second survey, entitled “OA exploration survey” was sent out to participants on April 24th. The survey consisted of 19 questions, two general questions about the OA explorations to be answered with a rubric, and 17 questions where teachers were asked to comment on specific strengths and weaknesses of the four OA explorations (see Appendix: OA Exploration Feedback). In order to encourage more feedback from this survey I did two things. I offered the workshop participants a deal by which if all six of them completed the survey by May 24th, each participant would receive two passes to the Birch Aquarium. I also emailed the participants weekly, reminding them of the survey, the opportunity for the passes to the aquarium, and providing them with the link to the survey website. All six of the participants completed the survey by May 20th.

An additional challenge that I ran into was that although all of the participants filled out the survey of the OA explorations, not all of them tried the explorations with their classrooms. One method that I might try differently in the future is based on how the EARTH program at the Monterey Bay Research Institute gets feedback from its teacher participants. Teacher training workshops are announced and teachers are able to go on the EARTH website and download lesson plans to try out with their classrooms. Teachers then complete a lesson plan review and sent that in along with their application to attend the workshop (EARTH 2013). This model has some drawbacks. If the subject matter of the lesson plans is very complex or requires additional training, the teachers will not have that by the time they conduct the lessons. The benefits to this model are that EARTH gets feedback on their lesson plans and all of the teachers come to the workshops with the shared experience of having tried out the lesson plans.
Participants can discuss challenges and successes, and take insight from each other’s experiences back with them to their classrooms to try the lessons out again the following year.

**Summary of Suggestions for Garnering Feedback**

- Paper survey for workshop feedback filled out at the end of the workshop
- If all participants provide feedback, they all get a reward
- Email participants weekly to remind them of surveys after workshop
- Teachers submit lesson reviews as part of their application to participate in workshop

**OA Exploration Feedback**

The ocean acidification workshop successfully met the objective to provide middle school teachers with the tools and knowledge to bring ocean acidification into their classrooms. Throughout the day the participants’ questions became more complex, displaying their comprehension of the subject matter. They progressed from general questions about chemical equations and terminology to inquiries into how marine ecosystems might be restructured by ocean acidification over time. The structure of the workshop, in which teachers learned background information first, then participated in the “OA explorations” and finally were able to tour the labs and interact with researchers, contributed to their understanding of the subject matter. As their understanding of the material grew and their questions became more complex, they were able to find answers either through the explorations or by talking to the researchers. By the end of the workshop, a few of the participants made comments like “I didn’t know what ocean acidification was before, and now I understand it”.

It was challenging to meet the second objective to reflect upon the integration of the lesson material into classrooms in order to inform the development of future workshops. This is because, as I mentioned earlier, it was difficult to ensure that the participants tried the explorations with their classrooms.

Two of the participants reported that they used the “OA exploration, part 1” with their classrooms. One of these participants stated that he or she “modified the lesson
and show[ed] the students baking soda and vinegar put into a universal indicator solution.” Another decided to use pH paper instead of cabbage juice indicator because he or she was “afraid that some students may misbehave and stain others garments on purpose”.

One participant modified “OA exploration, part 2”. The participant stated: “I modified the lesson and did not use sea water. I blew air (CO₂) into a test tube of universal indicator solution. The indicator turned reddish and was similar to the vinegar reaction color. The indicator changed back into it original color (green) after the test tube sat for an hour. I am guessing all the CO₂ evaporated out of the universal indicator solution”. The same participant took the OA exploration, part 4 and wrote a lesson for the students to write a paragraph on ocean acidification (see Appendix: Literature Activity).

The participants reported that they did not use any of the other three parts of the unit at the time of filling out the survey. Several participants stated that they “did not have enough time” to try out all of the OA exploration parts, one participant indicated that his or her school was on spring break for a month, and another said that he or she does not yet have a classroom. Teacher’s time constraints, school schedules, and classroom accessibility should be taken into consideration carefully in the design of future teacher’s training workshops.

Even with this low rate of classroom testing, the participants provided feedback on all parts of the OA explorations and some indicated that they would use them with their classrooms in the future.
Overall, the OA exploration unit...

- Interesting/motivating/exciting to students
- Adequate and/or adaptable to grade level
- Easily integrated with national standards
- Added adequate background information for teachers
- Had easy-to-follow instructions
- Well-defined objectives, relevant to the topic
- Was written clearly

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Summary of Participants’ Feedback:

- Write vocabulary with consideration for English language learners
- Account for safety, ease, and messiness of the materials (e.g. use pH paper and or universal indicator solution instead of cabbage juice indicator)
- Use easy reference tools e.g. color sheets (see Appendix: Red Cabbage pH Series) so that students can make the association between pH level and the changing color of the universal indicator
- Incorporate kinesthetic activities into lessons
- Relate the lessons back to the kid's daily lives (e.g. the use of the kid’s snack in OA exploration, part 4 or as one participant suggested “Maybe relating acidification to something tangible for students - (e.g. Drinking sodas, and "squeaky teeth" - relating to the enamel being stripped off of one's teeth by coming in contact with carbonated water. If tooth is left in soda overnight, begins to dissolve. (Weakens teeth the same as animals shells...)) Relating the plight of oceans to everyday health things - can help bridge the gap to the issues faced by ocean. Personal health and ocean health are (and should be) related.”)
- Use videos to demonstrate things like animal shells dissolving in the ocean that cannot easily be simulated in the classroom
- Provide the kids with short demonstrations that they can share with their families and friends
- Introduce and use scientific method
- Provide full lesson plans or enough material so that exercises can be developed into lesson plans
- Include questions and discussion topics in the curriculum material
- Include background material for the teachers so that they can be prepared to field students' bizarre questions
- Be explicit about the nature of the educational material that will be provided to the workshop participants and its intended use
Discussion

Avenues for Future Research and Work

As public education adapts to the changing environment of awareness about climate change, education research and innovative practices in science classrooms will help to shape new ways for middle school science to be taught. There are many useful tools and methods for the respective evaluation and practice of middle school science education. Some of the innovative practices in education will come about from a synthesis and recombination of these existent tools and methods. The following are just a few suggestions for future research and work in the field of middle school science education that I see as having great potential to improve teaching methods and our understanding of learning about climate change.

As states begin to change their science education standards based on the next generation science standards and integrate climate change into middle school classrooms, it would be interesting to use environmental knowledge surveys to establish a baseline of students’ and teachers’ understanding of climate change. This information could help education researchers and curriculum developers in the future to assess what areas of middle school climate change understanding have been improved by the introduction of climate change curricula.

In order to develop effective climate change curricula, curriculum developers and middle school science educators may look to some lessons from education research for successful and emerging practices in science education. Emerging practices that may improve science teaching include the integration of successful elements of place-based learning into traditional classrooms. Climate change curricula designed to foster student’s psychological ties to parts of the world, like the ocean, which stand to be greatly effected by human activities, may encourage student engagement in the topic. Integrating real-time data from a local source, for example the SWAMP research, into lesson plans for San Diego middle school classes, might be one way to foster students’ psychological ties to the environment. When possible, curricula should include field trips and other experiential learning to supplement the integration of real time data. For
example, students using the SWAMP data might benefit from trips to the Scripps Pier or local tide pools to practice collecting ocean acidification data themselves.

The integration of art into the traditional STEM disciplines, explored in the STEM to STEAM movement, is another emerging practice in science education that may enhance climate change curriculum. For example, teachers may use the material from the OA explorations to further develop interdisciplinary lesson plans to explore the topic.

Middle school teachers may be better prepared for the task of teaching climate change by participating in teacher’s training workshops. Best practices in the field of teacher training may be called out by developing a network of communication between teacher trainers and by conducting more research on effective teacher training methods.

Once new climate change curricula are introduced into middle school classrooms, the TOSRA may be applied to determine how the introduction of new curricula has impacted students’ understanding of and interest in science. The TOSRA may also be used to determine how student’s science attitudes are impacted by their teachers’ participation in a variety of climate-change-related teacher training workshops.

Finally, there are many opportunities to foster scientist-classroom partnerships in the future. Calls from funding agencies like the NSF for the integration of education and outreach in research proposals may create numerous opportunities for mutually beneficial relationships between researchers and middle school science students. For instance one might develop a step-wise plan to integrate the process of field research, data collection, and interpretation into middle school science lessons. These lessons could be supplemented with ongoing remote or real life interactions between scientists and students. This type of partnership could restructure middle school science classrooms so that students are engaged with real research and could benefit researchers by providing them with more data acquisition and interpretation as well as meaningful opportunities for outreach and education to broaden the impact of their research. Future teacher training workshops based in research institutions like Scripps Research institution may connect interested teachers and researchers and could serve as launching pads for these partnerships between classrooms and scientists.
Conclusion

In developing the OA explorations and conducting the workshop to introduce the material to middle school science teachers, I have begun to explore some ways that climate change topics can be effectively introduced into middle school classrooms and some of the challenges to doing this. The development of future workshops of this kind may benefit from the information about science education research and teacher training research that served as background for this project. Future workshops may also benefit from the feedback and lessons of this project. This project has illuminated questions and future opportunities for the integration of climate change into middle school science classrooms more than it has provided answers about how this integration should be done. I hope that this project, a real life application of inquiry learning, will inspire a ripple effect of inquiry in education researchers, climate change scientists, educators, and students of all ages, who may seek to answer the question, "how can we teach and learn about climate change?".
Bibliography


Achieve, Inc. et al. (2013) Next Generation Science Standards Middle School Physical Science Storyline-Middle School Engineering Design. Achieve, Inc. on behalf of the twenty-six states and partners that collaborated on the NGSS, 33-61


Appendix

Workshop Flyer

TEACHING OCEAN ACIDIFICATION TO MIDDLE SCHOOLERS

You are invited to participate in an interactive workshop at

Birch Aquarium at Scripps Institution of Oceanography on Saturday March 30, 2013 from 9am - 3pm.

Ocean Acidification, “the other CO2 problem”, is a new frontier in marine science.

This FREE workshop will:

-Demonstrate an Ocean Acidification lesson plan
-Provide materials for lesson plan and interdisciplinary exercises
-Explore cutting edge science and research
-Allow you to bring Ocean Acidification into your classroom!

Participants will be asked to engage in a lesson review with their classrooms and to provide feedback.

Workshop will also include:

Admission to the Aquarium
Visit to the Scripps Research Pier
Tour of research scientist Andreas Andersson’s Lab

...and light lunch!

To register by Monday March 25th, email egottgott@gmail.com with “OA workshop” in the subject line and your name, grade, and school in the body of the email.
OA Explorations

Ocean Acidification Exploration Part 1: Is Seawater More Like Vinegar or Soap?

Summary:
Students will explore the pH of seawater compared to vinegar, soap, carbonated water, and tap water. Class will use red cabbage juice as a pH indicator to determine the relative pH of these solutions.

Objectives:
Students will understand new terms and concepts:

- **pH** - a measure of how acidic or basic
- something is acid/acidic - a substance with a low pH (less than 7) base/basic - a substance with a high pH (greater than 7)
- pH indicator - a substance that can be added to a solution so that the pH of the solution can be seen
- solution - a mixture between two substances

They will be able to answer the questions in the “question/discussion” section (see below)

Safety:
Students should wear safety goggles while making the solutions. They should never mix the solutions with one another (i.e. once the soap solution has been made, it should not be mixed with the vinegar solution). Students should avoid touching eyes and mouths while preparing the solutions. They should wash hands thoroughly after handling the solutions.

Preparation and Materials:

**Teacher prep:**
Make cabbage juice indicator
See attached “Recipe for Cabbage Juice pH Indicator” Print attached “Red Cabbage pH Series”, one for each student

**Student prep:**
Make lab notebooks
See attached “Instructions for Making Lab Notebooks”

**Materials:**
- Straws, one per student (to use in part 2)
- Tall white paper cups, six cups per group of students
- 0.5 cup measuring cups, one per group
- Tablespoons, one per group
- Salt
- Clear vinegar Carbonated water Tap water
Seasalt

Additional resources:
The website "Middle School Chemistry" has some great lesson plans to introduce pH. The lessons build up to an introduction on carbon dioxide in seawater. Chapter 6, lessons 8-10 are most relevant. The following link will take you to the lesson plans:
http://www.middleschoolchemistry.com/lessonplans/

Lesson:
Students should work in small groups (3-5 students). Each group will make a solution of the following:
- Vinegar (1 tbsp/0.5 cup tap water)
- Soap (1 tbsp/0.5 cup tap water)
- Carbonated water (0.5 cup)
- Tap water (0.5 cup)
- Seawater (1 tbsp/0.5 cup tap water)
Each student should make four hypotheses in their lab notebooks: “Seawater will be (more/less) acidic than (vinegar/soap/carbonated water/tap water).” Then the students will add 0.5 cups of cabbage juice pH indicator to each solution. They will note the different colors in their lab notebooks and compare these colors to the color chart "Red Cabbage pH Series" to determine the corresponding pH. Students should then compare their results with their hypotheses.

Questions/Discussion:
Which pH numbers mean that a substance is acidic? Which pH numbers mean that a substance is basic?
What does a pH indicator do?
What colors, after we add the pH indicator, mean that a substance is acidic/basic?
Is seawater more/less acidic/basic than vinegar/soap/carbonated water/tap water?
Which four of the substances that we measured are solutions? Which one is not a solution?

This lesson plan has been adapted from Sarah Cooley’s “Ocean Acidification Lab” (2009) Ocean Carbon and Biogeochemistry Program, found at: http://www.us-ocb.org/publications/OCB-OA_labkit102609.pdf

Ocean Acidification Exploration Part 2:
How Does Seawater Resist Changes in pH?

Summary:
We can change the pH of a substance by adding acid or base to it, for example adding vinegar/soap to tap water (how did these additions change the pH of the tap water?)
Changing the pH of a substance is a chemical reaction. We know this because of the change in color shown by the pH indicator. Other additions, like adding carbon dioxide by blowing into water, will also change the pH by causing a chemical reaction. Some solutions are more resistant to changes in pH than others. For example, when we add carbon dioxide to seawater, the change in pH will be different from when we add carbon dioxide to tap water. (Teacher can demonstrate here by blowing into a cup of tap water with the pH indicator in it so students can observe the color change.) Different substances resist changes in pH differently than tap water. For instance, when we add carbon dioxide to seawater, the pH of the seawater will change at a different rate.

Objectives:
Students will understand new terms and concepts:
  - Resist changes in pH - property of a substance to change pH at a specific rate when an acid/or base is added
  - Rate - change over time
  - Ocean Acidification - decrease in the seawater’s pH as more carbon dioxide enters the ocean from the atmosphere over time

They will be able to answer the questions in the “question/discussion” section (see below)

Safety:
Students should wear safety goggles while conducting this experiment. They will be blowing into the water with straws, which might create some splashes. The cabbage indicator is harmless to swallow, although this should be avoided, but it may stain clothing. The safest way to blow into the water is use tall cups, put the straw all the way to the bottom of the cup and blow hard enough to create bubbles, but not so hard that the water splashes everywhere. The teacher should demonstrate this. Also, never suck the water up through the straw!

Preparation and materials:
Lab notebooks
Red Cabbage pH Series, one per student
Each group will use the tap water and the sea water with pH indicator in them from “part 1”
Straws, one per student

Additional resources:
Bermuda scooter video
This is a demonstration of the change in pH that occurs when carbon dioxide from another source, this time a scooter, is added to water. Show this as part of the discussion to illustrate how sources of carbon dioxide affect water’s pH.
Lesson:
Again, students should work in small groups.
Students should write their hypothesis, “Sea water will be more/less resistant to changes in pH than tap water when we add carbon dioxide to it.”
Students should take the seawater and tap water, with pH indicator in it, aside.
In their lab notebooks, students should record the initial colors and corresponding pH for the tap water and pH, using the “red cabbage pH series”.
Students should then take turns blowing into the two samples with a straw.
(Students can sit in a circle and blow into the tap water and salt water for 10 seconds and then pass the cups to the person on the left, and continue to do so until the two cups make a full circle. If no color change is observed in the tap water after one round, the cups should go around the circle again.)
After a few rounds, the students should observe any color change/pH change in the tap water and in the seawater. Again they should use the “red cabbage pH series” to determine the pH of the water.
Students should record their observations and compare them to their hypotheses.

Questions/Discussion:
What are we adding to the water when we blow into it?
Did the addition of carbon dioxide make the tap water more acidic or more basic? Did the addition of carbon dioxide make the seawater more acidic or more basic? What was the difference between the tap water and the seawater when we added carbon dioxide to both?
Is carbon dioxide an acid or a base?
Why do you think we observed this difference? What is different about seawater and tap water that might have caused them to resist changes in pH differently?

What we have observed here is seawater’s ability to resist changes in pH with the addition of carbon dioxide. The seawater in the ocean does the same thing as the seawater in our cups. As carbon dioxide is released into the atmosphere or air, it dissolves in the ocean, just like the carbon dioxide that we blew into the seawater with straws. The ocean is able to resist changes in pH when carbon dioxide is added because of the salt in the water. You can think of the salt as a sponge absorbing the carbon dioxide (note: this is just one of many aspects of the ocean that allows it to uptake carbon dioxide). But, just like sponges get full eventually and start to drip, the ocean will reach a point where there is too much carbon dioxide dissolving in it, it will become “full”, and the pH will change. Will the seawater become more acidic or more basic when the carbon dioxide begins to change the pH? Think about what happened to the tap water when we added carbon dioxide to answer this.

Humans put a lot of carbon dioxide into the atmosphere when they drive cars and run factories and cut down trees. The ocean has been helping to absorb a lot of that carbon dioxide, about 30%! But there is so much carbon dioxide in the atmosphere that the ocean is starting to get acidic. This is called Ocean Acidification.
Ocean Acidification Exploration Part 3
How Will Marine Animals With Shells Respond to Changes in Seawater’s pH?

Summary:
Calcium carbonate is the building block for many marine animals’ shells (what are some animals that live in the ocean and have shells?). When carbon dioxide, or another acid, is added to seawater a chemical reaction occurs with calcium carbonate. This reaction is called dissolution. Eggshells are made of calcium carbonate, just like marine animal shells. We are going to see what happens when we put eggshells in a strong acid, vinegar. We will observe what happens to calcium carbonate in an acid and to see exactly what dissolution means. In this experiment we will be observing both dissolution and change in pH. These two chemical reactions are connected, and we are going to see why.

Objectives:
Students will understand new terms and concepts:
- Calcium carbonate - the building block for marine animal shells and eggshells
- Dissolution - when a solid substance, like calcium carbonate, reacts with a liquid

Safety:
Students should wear safety goggles while handling the vinegar. When it comes time to remove the eggs from the water and the vinegar (day two) they should do so carefully with a spoon, and place the eggs down on a “nest” of paper towel to prevent them from rolling. They should avoid contact with eyes and mouth and wash hands thoroughly after handling the vinegar and the eggs.

Preparation and materials:
Teacher prep:
Make hard-boiled eggs, you can decide whether each student should have his/her own egg and vinegar set-up or whether there should be one set-up per group. Each set-up needs two eggs, one in water, as a control, and one in vinegar.
Other materials:
- Lab notebooks
- Red Cabbage pH Series, one per student
- Clear vinegar
- Tap water
- Plastic or glass cups (paper cups might leak overnight), two per set-up
- Paper towel

Additional Resources:
For Teachers:
(I will email the PDFs of these articles to you)
Ries (2011) - talks about different organisms responses to lower pH Iglesias-Rodriguez et. al. (2008) - experiment that used carbon dioxide to simulate future ocean pH and to see what would happen to calcifying organisms Reibesell et. al. (2000) - experiment that
used acid to simulate future ocean pH and to see what would happen to calcifying organisms

For Class:
Videos do a great job of illustrating ocean acidification and related dissolution to supplement discussion of this experiment-

Simpler:
Ocean Acidification, published by NCAquariumFortFisher
http://www.youtube.com/watch?v=kxPwbhFeZSw

More detailed:
NOAA Ocean Acidification - The Other Carbon Dioxide Problem, published by GlobalClimateNews
http://www.youtube.com/watch?v=MgdIAt4CR-4

Lesson, Day 1:
Students should write down hypotheses in their lab notebooks e.g. “The egg shells will get thinner/will bubble/will not change in the acid.” [without telling them what dissolution is exactly, because they are going to see it with their own eyes] The students should gently place two eggs into two empty cups and add water and vinegar until there is enough liquid to cover the eggs. Then they should add 0.5 cups of the pH indicator to each cup. Then they should write down any initial observations in their lab notebooks, including the initial color/pH of the water and vinegar, and any initial changes to the eggshells. The eggs will be left in the water and vinegar overnight.

Questions/Discussion, Day 1:
Why do you think the egg in the vinegar began to bubble and the egg in the water did not?
What do you think those bubble are made of? [carbon dioxide] Will those bubbles change the pH of the vinegar?
Will we see a change in the pH of the water?

Lesson, Day 2:
Students should record any changes in color/pH of the tap water and the vinegar. They should also record any changes in the eggs that they can see/hear (bubbling) before they take the eggs out. Then students should remove the eggs carefully with a spoon and place them on paper towels. They should observe the eggs using all of their senses (except for taste, please!) and record their observations in their lab notebooks. They should compare their observations with their hypotheses.

Questions/Discussion day 2:
Why is the eggshell from the vinegar different than the eggshell from the tap water? Based on your observations, what is a definition of dissolution? What do you think would happen to marine animals with shells in an ocean that was as acidic as vinegar?
This experiment is an exaggeration. We discussed in lesson 2 that oceans are becoming more acidic because more carbon dioxide is dissolving in them. This is called ocean acidification. But oceans are not anywhere near as acidic as vinegar and, no matter how much carbon dioxide is in the atmosphere, they will not become as acidic as vinegar in the future. What was the pH of seawater that we observed in lesson 1? [should be around 7-8]. The ocean’s pH is about 8.1. Before the industrial revolution, when lots of factories were built, and trains and cars were invented, and people began to cut down lots of trees to build houses and roads, the ocean’s pH was about 8.2. Some scientists predict that if we keep putting carbon dioxide into the atmosphere at the rate we are going, the ocean’s pH will be about 7.8 by 2100. How old will you be in 2100?

Vinegar has a pH of about 2, so you can see that it is much more acidic than the ocean is, or ever will be. Scientists create experiments like this, or simulations, where they put shelled ocean animals in water with a pH similar to what it might be in the future to see how the animals react and to see what happens to their shells. These experiments take a very long time to run. So we used this exaggeration to demonstrate what might happen to calcium carbonate shells in more acidic water, in a short enough period of time for you to see.

Discussion for advanced students:
There is one more thing that is inaccurate about using this demonstration to show the affects of ocean acidification on calcifying marine animals!
Humans are adding carbon dioxide, not acid, to the ocean. The addition of acid to seawater decreases the seawater’s pH. The addition of carbon dioxide to seawater decreases the seawater’s pH too, and it also increases the “dissolved inorganic carbon” in the water. This basically means that there is more carbon in the water that could, to a certain extent, help to replace some of the lost building block materials for shells.

Some experiments have shown that under future conditions of atmospheric carbon dioxide, some shelly marine animals do not lose their shell mass, some even increase their shell mass! One possible explanation for this is that the animals compromise some other activity, like searching for food or hiding from predators to keep building their shells under difficult conditions. It is also possible that some animals will be able to adapt over generations to changes in seawater pH. One of the biggest challenges for scientists who are studying ocean acidification is to figure out how different marine animals will change with changing ocean pH.

Challenge for advanced students:
Design an experiment to test how marine organisms with shells might change/adjust/adapt to predicted future changes in ocean pH.

Ocean Acidification Exploration Part 4
Adjust or Go Extinct!
Summary:
Some marine animals will not be able to form their shells in water as it becomes more acidic because of carbon dioxide emissions. These animals might be food for other animals, prey. This means that the animals that eat them, predators, will either have to adjust, by eating different food, or go extinct. One example is the pteropods from the NOAA video. Pteropods are known as the “potato chips of the sea” because they are a tasty snack for many marine animals and there are lots of them in the sea. Students will explore the problem that some marine predators will face in the future as they lose their prey because of ocean acidification.

Objectives:
Students will understand how ocean acidification could affect food sources for some marine animals and how those marine animals can either adjust by changing their food source, or go extinct. They will also be able to answer the questions in the “questions/discussion” section.

Preparation and Materials:
White board/chalk board and something to write with

Additional Resources:
Additional lesson plans that explore coral reef organisms’ adjustments and adaptations to ocean acidification:
NOAA’s coral reef conservation program: student activities
http://coralreef.noaa.gov/education/educators/resourcecd/activities/

Article summarizing the consequences that ocean acidification could have for different organisms, great background reading for teachers or advanced students:

Lesson:
Teacher should ask the students to name some of their favorite tasty snacks and list them on the board. Then students should name some of the healthiest foods they can think of and list those on the board. The two lists should then be narrowed down, by popular vote, to three tasty and three healthy snacks. Then all students should be asked to decide between one of the six snacks or no snack at all, and their choices should be tally marked by each snack. Then the teacher should explain that all the ingredients to make the most popular snack have run out, remove it from the list, have students vote again, they can still choose no snack, and record the votes with tally marks. This should be repeated with the next most popular snack, and again until there is only one snack option and the “no snack” option left.

Questions/Discussion:
If we lived in a world where these snacks listed on the board were the only food available for us to eat, what would have happened to us as the snacks went extinct?
Who of us would have survived at the end by adjusting to the only snack left and who would have gone extinct?
What do you think will happen to marine animals as some of their food goes extinct because of ocean acidification?
How could that affect people?

Red cabbage pH series

Cabbage Juice pH Indicator Recipe
Take one red cabbage and chop roughly. Separate as many pieces as possible. Place cabbage in large pot and cover with water. Heat pot on stove with lid on. Watch that it does not boil over. Heat for 30 minutes to one hour or until liquid is dark purple. Strain cabbage pieces from the liquid, and allow the liquid to cool. Store liquid in refrigerator until ready for use.

Instructions for Making Lab Notebooks
Step 1: fold one piece of paper in half “hamburger style” and cut slot according to figure “A”
Step 2: fold another piece of paper (or more depending on how many pages you want in your notebook) in half “hamburger style” and cut notches according to figure “B”
Step 3: fold “B” page/pages in half “hot dog style” but DO NOT CREASE
Step 4: insert “B” pages into “A” page slot and then twist until the notches in “B” fit into the slot in “A”
Literature Activity

Written by workshop participant, Lesley Gregory.

Coral Reef Rescue: Ocean Acidification

As a warming climate changes the chemistry of Earth’s oceans, scientists look for ways to save coral (show brain pop, coral)
http://www.youtube.com/watch?v=kxPwbhFeZSw&feature=player_detailpage

Scientist Erich Bartels sometimes spends six hours a day on the ocean floor of Florida’s Mote Marine Laboratory. He works among fish, dolphins, crabs, and snails. They all come for the same thing that Bartels is trying to save: coral. Many species depend on coral reefs to survive. “Without coral, much of the ocean would just be a barren plain,” he says.

But because of climate change, coral reefs are at risk. Ocean waters are becoming more acidic, making it harder for corals and shellfish to grow. This side effect of climate
change has made coral reefs one of the world’s most endangered ecosystems. Roughly 75 percent of coral reefs are currently at risk of disappearing.

**Important Environments**

From sea horses to sea turtles, many marine animals rely on reefs. Coral reefs are sort of like the rainforests of the ocean. Although they cover less than 1 percent of the ocean floor, coral reefs are home to 25 percent of all marine species. Corals are also important to people. Reefs protect our shorelines from storms. They provide shelter and a place to reproduce for the fish we depend on for food. Some animals found in coral reefs also contain chemicals that could be used to treat diseases. One cancer drug was developed from material found in sea sponges that live in coral reefs.

**Dangerous Waters**

Corals look like plants, but they aren’t. Coral reefs are actually colonies of individual animals. These animals build skeletons out of calcium carbonate. It’s a substance similar to limestone.

Coral reefs are threatened by many factors, including pollution and warming water temperatures. Another big problem, scientists say, is that the ocean is becoming more acidic. Burning fossil fuels to power cars make electricity, and heat homes gives off a gas called carbon dioxide. The gas goes into Earth’s atmosphere. A lot of it dissolves in the ocean. Carbon dioxide changes the chemistry of the ocean water, making it more acidic. Between 1751 and 2004 surface ocean pH is estimated to have decreased from approximately 8.25 to 8.14. The CO2 is released from burning fossil fuels and biomass. The CO2 is released and 45% of the CO2 goes into the atmosphere, 29% is absorbed by plants and trees (photosynthesis), and 26% is absorbed into our oceans. This change is tough on some marine life. The acid makes it hard for the corals to grow and the shells begin to dissolve. Without a calcium carbonate home, corals can’t survive.

**Saving Reefs**

Coral reef scientists like Bartels are working to find ways to help corals survive in the changing ocean. Bartels and his team grow baby corals in Mote Marine Laboratory’s ocean nursery off the Florida coast. When the corals are big enough, the team replants them on an existing reef.

The nursery project is giving scientist some hope. Bartels and his team watch to see which corals grow best in today’s warmer, more acidic ocean. By identifying the hardiest corals and replanting these species, the team may strengthen the reef.

Other scientists are trying different ideas. Mote’s Kim Ritchie studies the bacteria-tiny, one celled creatures-that live on the surface of corals. Ritchie thinks some bacteria may play a key role in keeping corals healthy. When the water’s temperature or acidity changes, these bacteria may disappear. That leaves corals at risk for disease. “We are finding out what corals need to stay healthy,” says Ritchie. The researchers are hoping to find solutions quickly. If nothing is done, they predict that the number of threatened reefs will rise to 100 percent by the year 2050. “We need to figure something out now,” says Bartels.
~Stephanie Warren, Scholastic Super Science Magazine May 2013 (Losers: shell critters Winners: jelly fish)

Procedure:
Show acid – base using universal indicator- test tube- straw - blow CO2 into test tube
Show brain pop, coral reefs……
1) (60 seconds to) underline title, sub title, captions. Write on bottom of paper one sentence about the topic.
2) Put everything aside and read the article…. Put pencil down…No underlining
3) Number each paragraph,
   Read article again and write the main idea next to each paragraph,
   Underline evidence that supports the main idea.
4) Show you tube video – address top of article
5) Teacher presents all question at a once for students to answer – students must support their answer with evidence and paragraph number
6) Write a paragraph

Paragraph outline for students: Higher level critical thinking

TS -Topic sentence – Ocean Acidification
Detail - 2 facts about corals
Detail - 2 reasons why corals are important
Detail – What is causing the coral reef to die?
Detail – How are they are trying to save corals?
Detail - Explain why/why not you think it is important to save corals
Commentary – Concluding Sentence

Questions: Lower level critical thinking
1. Explain two ways coral reefs are important (used for) P#
2. What gives off carbon dioxide? P#
3. What makes the ocean more acidic? P#
4. What grows in the Mote Marine Laboratory’s? P#
5. What do they believe that can keep the coral healthy? P#

Questions:
1. Explain two ways coral reefs are important (used for) P# 3-4
   Home or shelter and medicine
2. What gives off carbon dioxide? P#6
   Burning Fossil fuel and biomass give off CO2
3. What makes the ocean more acidic? P#6
   CO2 +H2O = acid---- stops growth and dissolves shells
4. What grows in the Mote Marine Laboratory’s? P#7
   Baby coral reefs to replant into the oceans coral reefs
5. What do they believe that can keep the coral healthy? P#9
   Bacteria keep the coral healthy
**OA Background Presentation**

**Ocean Acidification**
- What is Ocean Acidification?
- Who will Ocean Acidification Affect?
- Why Should We Teach OA?

**Carbon Chemistry**
- \( \text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \)
- \( \text{H}_2\text{CO}_3 \leftrightarrow \text{HCO}_3^- + \text{H}^+ \)
- \( \text{HCO}_3^- \leftrightarrow \text{CO}_3^{2-} + \text{H}^+ \)
- \( \text{H}_2\text{O} + \text{CO}_2 + \text{CO}_3^{2-} \leftrightarrow 2\text{HCO}_3^- \)

**Human Connection**

**Atmospheric Carbon**
- Atmospheric Carbon Dioxide Measured at Mauna Loa, Hawaii

**Global Surface Warming**
- Global Surface warming (°C)
- Year 2000 Standard (Steady)
- Year 2050 Steady (Steady)
- Year 2050 Steady (Increased)
Emily Gottlieb
The Changing Climate of Science Education: Bringing Ocean Acidification to Middle School Teachers

**Ocean Connection**
Where does anthropogenic carbon go?

- 1.4 PgC yr\(^{-1}\) (45%)
- 2.3 PgC yr\(^{-1}\) (26%)
- 2.9 PgC yr\(^{-1}\) (29%)

**Ocean Connection**
Link Between CO\(_2\) (atm) and Ocean pH

**Ocean Acidification**
Decrease in Sea Surface pH

- What is Ocean Acidification?
- Who will Ocean Acidification Affect?
  - Marine Organisms
  - Trophic Cascade
  - Humans

**Marine Organisms**
- [http://www.youtube.com/watch?v=kxPwhFeZSw&feature=em-share_video_user](http://www.youtube.com/watch?v=kxPwhFeZSw&feature=em-share_video_user)

**Marine Organisms**
Differential Response of Calcareous Organisms
Emily Gottlieb
The Changing Climate of Science Education: Bringing Ocean Acidification to Middle School Teachers

“Human Connection: Atmospheric Carbon” Photo credit: http://www.esrl.noaa.gov/gmd/ccgg/trends/
“Ocean Connection: Where does anthropogenic carbon go?” slide credit: Andreas Andersson 2013
“Ocean Connection: Link Between CO2 and Ocean pH” Slide credit: Andreas Andersson 2013
“Ocean Connection: Decrease in Sea Surface pH” Photo credit: http://www.pacificscience.org/tfoceanacidification.html
“Marine Organisms: Differential Response of Calcifying Organisms” Photo credit: Ries 2011
**Workshop Feedback**

Overall, how would you rate the workshop?

<table>
<thead>
<tr>
<th>Part</th>
<th>Excellent</th>
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<th>Fair</th>
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Did we allow enough time for each part of the workshop?

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<th>Just enough time</th>
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<tr>
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<td>3</td>
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<tr>
<td>Andersson Lab Visit</td>
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<tr>
<td>Smith Lab Visit</td>
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<td>Scripps Pier Visit</td>
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For future workshops may I suggest a shuttle of some sort for transportation down the hill and back up. Or perhaps give the participants a heads up before hand that there will be a lot of walking involved.
Will you bring the OA explorations into your classroom/s?

<table>
<thead>
<tr>
<th>Answer Choices</th>
<th>Responses</th>
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<tbody>
<tr>
<td>Yes, I will use all of the OA Exploration with my classroom/s</td>
<td>0% 0</td>
</tr>
<tr>
<td>Yes, I will use some parts of the OA Exploration with my classroom/s</td>
<td>66.67% 2</td>
</tr>
<tr>
<td>Yes, I will use some parts of the OA Exploration with my classroom/s, but I will modify them</td>
<td>0% 0</td>
</tr>
<tr>
<td>No, I will not use any parts of the OA Exploration with my classroom/s</td>
<td>0% 0</td>
</tr>
<tr>
<td>Other (please specify) Responses</td>
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I do not think I can complete all the lessons this year due to having to teach Life Skills and Sex Education. I intend to start earlier next year so that I can complete all the lessons.

5/9/2013 11:56 AM  View respondent's answers

Would you participate in a similar workshop in the future?

<table>
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<th>Answer Choices</th>
<th>Responses</th>
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<tbody>
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<td>Yes</td>
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<tr>
<td>No</td>
<td>0% 0</td>
</tr>
<tr>
<td>Other (please specify)</td>
<td>0% 0</td>
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<tr>
<td>Total</td>
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**OA Exploration Feedback**

Overall the OA exploration unit...
Overall the activities...

<table>
<thead>
<tr>
<th>Not at all</th>
<th>Somewhat</th>
<th>Adequate</th>
<th>Good</th>
<th>Excellent</th>
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<tbody>
<tr>
<td>were consistent with unit objectives</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>16.67%</td>
<td>83.33%</td>
</tr>
<tr>
<td>build upon one another in a way that makes sense</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>16.67%</td>
<td>83.33%</td>
</tr>
<tr>
<td>included hands-on components</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>9%</td>
<td>100%</td>
</tr>
<tr>
<td>included inquiry-based/problem-solving components</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>33.33%</td>
<td>66.67%</td>
</tr>
<tr>
<td>engaged students in the scientific process</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>16.67%</td>
<td>83.33%</td>
</tr>
<tr>
<td>were appropriate for a variety of learning styles</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>33.33%</td>
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<tr>
<td>included sufficient extension activities</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
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<td>66.67%</td>
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<tr>
<td>adequately taught the concepts</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>16.67%</td>
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</table>

Did you use “OA exploration, part 1” with your classroom?

<table>
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<tr>
<th>Answer Choices</th>
<th>Responses</th>
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</thead>
<tbody>
<tr>
<td>yes</td>
<td>33.33%</td>
</tr>
<tr>
<td>no</td>
<td>66.67%</td>
</tr>
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</table>

I have not yet obtained my own classroom.
5/20/2013 1:25 PM View respondent's answers

I have not developed the curriculum yet in order to implement in the classroom
5/6/2013 3:12 PM View respondent's answers

Not yet, we were on spring break for a month!
4/29/2013 3:26 PM View respondent's answers

I modified the lesson and show the students baking soda and vinegar put into a universal indicator solution.
4/24/2013 10:08 PM View respondent's answers
What were the strengths of “OA exploration, part 1”?

<table>
<thead>
<tr>
<th>Comment</th>
<th>Date</th>
<th>Time</th>
<th>View respondent's answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual, kinesthetic, relates to the larger world. Something quite interesting for students to share with family and friends.</td>
<td>5/20/2013</td>
<td>1:25 PM</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>Use of the color charts so students could see the color vs the pH level association</td>
<td>5/15/2013</td>
<td>9:57 AM</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>The questions at the end were well written</td>
<td>5/6/2013</td>
<td>3:12 PM</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>na</td>
<td>4/30/2013</td>
<td>7:38 AM</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>Hands on activities</td>
<td>4/29/2013</td>
<td>3:26 PM</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>explaining the process was very clear</td>
<td>4/24/2013</td>
<td>10:08 PM</td>
<td>View respondent's answers</td>
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</table>

What were the weaknesses of “OA exploration, part 1”?

<table>
<thead>
<tr>
<th>Comment</th>
<th>Date</th>
<th>Time</th>
<th>View respondent's answers</th>
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<tbody>
<tr>
<td>none</td>
<td>5/20/2013</td>
<td>1:25 PM</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>None</td>
<td>5/15/2013</td>
<td>9:57 AM</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>Is great for a demonstration however it could be expanded for a full lesson</td>
<td>5/6/2013</td>
<td>3:12 PM</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>na</td>
<td>4/30/2013</td>
<td>7:38 AM</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>differentiation of lesson - focused on lab and background research, could differentiate more.</td>
<td>4/29/2013</td>
<td>3:26 PM</td>
<td>View respondent's answers</td>
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<tr>
<td>none at this time</td>
<td>4/24/2013</td>
<td>10:08 PM</td>
<td>View respondent's answers</td>
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What modifications are needed to improve “part 1”?

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<td>View respondent's answers</td>
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<tr>
<td>5/20/2013 1:25 PM</td>
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<tr>
<td>I decided to use pH paper instead of the cabbage juice. I was afraid that some students may misbehave and stain others garments on purpose. I did not want to deal with irate parents</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>5/15/2013 9:57 AM</td>
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<tr>
<td>More detail to expand for a full lesson</td>
<td>View respondent's answers</td>
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<td>5/6/2013 3:12 PM</td>
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<tr>
<td>na</td>
<td>View respondent's answers</td>
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<tr>
<td>4/30/2013 7:38 AM</td>
<td></td>
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<tr>
<td>English Learners may have difficulty with vocabulary</td>
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<td>4/29/2013 3:26 PM</td>
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</tr>
<tr>
<td>I think universal indicator is better than cabbage juice indicator for PH. In my opinion....</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>4/24/2013 10:08 PM</td>
<td></td>
</tr>
</tbody>
</table>

Did you use “OA exploration, part 2” with your classroom?

<table>
<thead>
<tr>
<th>Answer Choices</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>yes</td>
<td>0%</td>
</tr>
<tr>
<td>no</td>
<td>100%</td>
</tr>
<tr>
<td>Total</td>
<td>6</td>
</tr>
</tbody>
</table>

No
5/20/2013 1:25 PM View respondent's answers

Time constraints
5/15/2013 9:59 AM View respondent's answers

Have not had time!
5/15/2013 9:17 AM View respondent's answers

have not developed the curriculum yet in order to use in the classroom
5/6/2013 3:15 PM View respondent's answers

not enough time to get sea water. So, I simplified activity.
4/24/2013 10:17 PM View respondent's answers

What were the strengths of “OA exploration, part 2”?

<table>
<thead>
<tr>
<th>Comment</th>
<th>Date</th>
<th>Time</th>
<th>View respondent's answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>oh - I think I put that on part 1.</td>
<td>5/20/2013 1:25 PM</td>
<td>View respondent's answers</td>
<td></td>
</tr>
<tr>
<td>Hands-on with the blowing into the straws.</td>
<td>5/15/2013 9:59 AM</td>
<td>View respondent's answers</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td>5/15/2013 9:17 AM</td>
<td>View respondent's answers</td>
<td></td>
</tr>
<tr>
<td>good introduction to scientific method. having them use a science notebook is a great habit to build</td>
<td>5/6/2013 3:15 PM</td>
<td>View respondent's answers</td>
<td></td>
</tr>
<tr>
<td>na</td>
<td>4/30/2013 7:39 AM</td>
<td>View respondent's answers</td>
<td></td>
</tr>
<tr>
<td>none at this time</td>
<td>4/24/2013 10:17 PM</td>
<td>View respondent's answers</td>
<td></td>
</tr>
</tbody>
</table>

What were the weaknesses of “OA exploration, part 2”?

<table>
<thead>
<tr>
<th>Comment</th>
<th>Date</th>
<th>Time</th>
<th>View respondent's answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can be messy if students aren't careful. Students will need to wear clothes which won't be stained.</td>
<td>5/20/2013 1:25 PM</td>
<td>View respondent's answers</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>5/15/2013 9:59 AM</td>
<td>View respondent's answers</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td>5/15/2013 9:17 AM</td>
<td>View respondent's answers</td>
<td></td>
</tr>
<tr>
<td>It is great for a quick demonstration. perhaps it could be apart of a larger lesson</td>
<td>5/6/2013 3:15 PM</td>
<td>View respondent's answers</td>
<td></td>
</tr>
<tr>
<td>na</td>
<td>4/30/2013 7:39 AM</td>
<td>View respondent's answers</td>
<td></td>
</tr>
<tr>
<td>One of my students ingested the indicator solution through the straw and said he became sick. He was instructed to exhale into the straw. Next time, the teacher will exhale into the straw.</td>
<td>4/24/2013 10:17 PM</td>
<td>View respondent's answers</td>
<td></td>
</tr>
</tbody>
</table>
What modifications are needed to improve “part 2”?

<table>
<thead>
<tr>
<th>Answer</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>none</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>N/A</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>while the students are blowing into the sample perhaps the other students should be engaged somehow as well, perhaps through discussion</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>na</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>I modified the lesson and did not use sea water. I blew air (co2) into a test tube of universal indicator solution. The indicator turned reddish and was similar to the vinegar reaction color. The indicator changed back into it original color (green) after the test tube sat for an hour. I am guessing all the CO2 evaporated out of the universal indicator solution.</td>
<td>View respondent's answers</td>
</tr>
</tbody>
</table>

Did you use “OA exploration, part 3” with your classroom?

<table>
<thead>
<tr>
<th>Answer Choices</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>yes</td>
<td>0%</td>
</tr>
<tr>
<td>no</td>
<td>100%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Answer</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>no classroom yet.</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>Time constraints</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>No time! It will happen later in the year.</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>have not developed the curriculum to use in the classroom</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>this lesson is done in 7th grade and I teach 6th grade</td>
<td>View respondent's answers</td>
</tr>
</tbody>
</table>
What are the strengths of “OA exploration, part 3”?

<table>
<thead>
<tr>
<th>Comment</th>
<th>Date</th>
<th>Time</th>
<th>View respondent's answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very good information and comparisons - as far as slides.</td>
<td>5/20/2013 1:29 PM</td>
<td>View respondent's answers</td>
<td></td>
</tr>
<tr>
<td>Use of videos</td>
<td>5/15/2013 10:02 AM</td>
<td>View respondent's answers</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td>5/15/2013 9:17 AM</td>
<td>View respondent's answers</td>
<td></td>
</tr>
<tr>
<td>Great incorporation between real science articles and the lesson. The video is excellent as well.</td>
<td>5/6/2013 3:18 PM</td>
<td>View respondent's answers</td>
<td></td>
</tr>
<tr>
<td>Na</td>
<td>4/30/2013 7:39 AM</td>
<td>View respondent's answers</td>
<td></td>
</tr>
<tr>
<td>None at this time</td>
<td>4/24/2013 10:18 PM</td>
<td>View respondent's answers</td>
<td></td>
</tr>
</tbody>
</table>

What are the weaknesses of “OA exploration, part 3”?

<table>
<thead>
<tr>
<th>Comment</th>
<th>Date</th>
<th>Time</th>
<th>View respondent's answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Could have a greater kinesthetic component.</td>
<td>5/20/2013 1:29 PM</td>
<td>View respondent's answers</td>
<td></td>
</tr>
<tr>
<td>None, except we are on block schedule and only see the kids every other day.</td>
<td>5/15/2013 10:02 AM</td>
<td>View respondent's answers</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td>5/15/2013 9:17 AM</td>
<td>View respondent's answers</td>
<td></td>
</tr>
<tr>
<td>This lends to be a great example of a longer lesson since it is over a span of two days</td>
<td>5/6/2013 3:18 PM</td>
<td>View respondent's answers</td>
<td></td>
</tr>
<tr>
<td>Na</td>
<td>4/30/2013 7:39 AM</td>
<td>View respondent's answers</td>
<td></td>
</tr>
<tr>
<td>None at this time</td>
<td>4/24/2013 10:18 PM</td>
<td>View respondent's answers</td>
<td></td>
</tr>
</tbody>
</table>
What modifications are needed to improve “part 3”?

Dissolving shells overnight in mildly acidic sea water. Maybe a video showing animals shells deteriorating.
5/20/2013 1:29 PM View respondent's answers

None
5/15/2013 10:02 AM View respondent's answers

N/A
5/15/2013 9:17 AM View respondent's answers

perhaps a longer term experiment of having a less extreme example of acidic conditions. maybe have a set up in the classroom that lasts a few weeks so that the students can see the long term affects.
5/6/2013 3:18 PM View respondent's answers

na
4/30/2013 7:39 AM View respondent's answers

none at this time
4/24/2013 10:18 PM View respondent's answers

Did you use “OA exploration, part 4” with your classroom?

<table>
<thead>
<tr>
<th>Answer Choices</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>yes</td>
<td>0%</td>
</tr>
<tr>
<td>no</td>
<td>100%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
</tbody>
</table>

no classroom
5/20/2013 1:30 PM View respondent's answers

Time constraints
5/15/2013 10:13 AM View respondent's answers

Same as above!
5/15/2013 9:18 AM View respondent's answers

have not developed the curriculum yet to use in the classroom
5/8/2013 3:21 PM View respondent's answers

not enough time
4/24/2013 10:21 PM View respondent's answers
What are the strengths of “OA exploration, part 4”?  

<table>
<thead>
<tr>
<th>Strength</th>
<th>Timestamp</th>
<th>View respondent's answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good information - such an important subject.</td>
<td>5/20/2013 1:30 PM</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>Extinction question is good about their favorite snack. This help them get the connection about being able to adapt.</td>
<td>5/15/2013 10:13 AM</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>N/A</td>
<td>5/15/2013 9:18 AM</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>great introduction to the food web and connections</td>
<td>5/6/2013 3:21 PM</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>na</td>
<td>4/30/2013 7:39 AM</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>the video to explain the chemical reaction of CO2 and calcium carbonate.</td>
<td>4/24/2013 10:21 PM</td>
<td>View respondent's answers</td>
</tr>
</tbody>
</table>

What are the weaknesses of “OA exploration, part 4”?  

<table>
<thead>
<tr>
<th>Weakness</th>
<th>Timestamp</th>
<th>View respondent's answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>none</td>
<td>5/20/2013 1:30 PM</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>None</td>
<td>5/15/2013 10:13 AM</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>N/A</td>
<td>5/15/2013 9:18 AM</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>It is very short although engaging and easy for them to understand</td>
<td>5/6/2013 3:21 PM</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>na</td>
<td>4/30/2013 7:39 AM</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>none at this time.</td>
<td>4/24/2013 10:21 PM</td>
<td>View respondent's answers</td>
</tr>
</tbody>
</table>
What modifications are needed to improve “part 4”?

<table>
<thead>
<tr>
<th>User</th>
<th>Date/Time</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>none</td>
<td>5/20/2013 1:30 PM</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>You might give some other possible adaptation scenarios. Some of us have multiple classes and students can then have a new issue to consider.</td>
<td>5/15/2013 10:13 AM</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>N/A</td>
<td>5/15/2013 9:18 AM</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>have more incorporation of OA, perhaps bring in live food sources that are greatly affected by OA like crabs.</td>
<td>5/6/2013 3:21 PM</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>na</td>
<td>4/30/2013 7:39 AM</td>
<td>View respondent's answers</td>
</tr>
<tr>
<td>I took this lesson wrote a lesson for students to write a paragraph on OA. I did forward this lesson to Emily.</td>
<td>4/24/2013 10:21 PM</td>
<td>View respondent's answers</td>
</tr>
</tbody>
</table>

Please include any additional comments or resources that might be useful to teachers who will use this OA exploration unit in the future.

Maybe relating acidification to something tangible for students - e.g. Drinking sodas, and "squeaky teeth" - relating to the enamel being stripped off of one's teeth by coming in contact with carbonated water. If tooth is left in soda overnight, begins to dissolve. (Weakens teeth the same as animals shells...) Relating the plight of oceans to everyday health things - can help bridge the gap to the issues faced by ocean. Personal health and ocean health are (and should be) related. | 5/20/2013 1:37 PM | View respondent's answers                                                                                                                    |

These lessons and the additional information that was provided in the workshop was very thorough. Students will ask bizarre questions so be sure to have some background knowledge of the organisms that you will be discussing. | 5/6/2013 3:22 PM | View respondent's answers                                                                                                                    |

none to give! | 4/30/2013 7:40 AM | View respondent's answers                                                                                                                    |

great lesson. I was not clear about OA before the lesson and Emily made OA understandable. | 4/24/2013 10:22 PM | View respondent's answers                                                                                                                    |