Title
Changing Climate in the Classroom: A model for place-based climate science education in San Diego County

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Changing Climate in the Classroom:
A model for place-based climate science education in San Diego County

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Changing Climate in the Classroom:  
A Model for Place-based Climate Science Education in San Diego County

Abstract

Climate change is a phenomenon that has sweeping impacts across the globe. Rising concentrations of greenhouse gases are leading to increased mean global air and ocean temperatures. These changes contribute to problems that have societal, environmental, and financial implications. Climate change education is becoming increasingly relevant as today’s students will face threats such as sea level rise, changes in the frequency and intensity of droughts and storms, loss of biodiversity, and others as climate-related impacts worsen. Yet, students currently lack a comprehensive understanding of the mechanisms of climate change. In order to address the problems associated with climate change, students must be knowledgeable, engaged in finding solutions, and be motivated to take action. This project sought to develop a curriculum through a place-based framework that can enhance students’ understanding of the causes and effects of climate change, as well as the possible solutions in addressing this global problem on local scales.

I developed a curriculum on the subjects of climate change and coastal ecosystems which includes a series of three lessons, in-class activities, a laboratory experiment, and a boat-based field experience. I administered the unit to 47 tenth grade students at High Tech High North County. To assess the effectiveness of the curriculum I administered the same assessment prior to and following the presentation of the lessons. The results show that students’ scores improved significantly after receiving the lessons when subjected to a paired t test providing evidence that students gained an improved awareness about local climate change issues and solutions. Additionally, student feedback qualitatively yielded positive results, demonstrating the efficacy of the curriculum as a tool for teaching high school students about climate science.

Introduction

Climate change is a subject that is growing in significance and relevance as we experience the global consequences of a changing climate. The world’s oceans are increasingly subject to climate-related impacts and the effects of a warmer climate will have many consequences for coastal and marine ecosystems (Scavia et al., 2002). Some of these impacts “may substantially alter human dependencies and interactions with these complex and linked systems” (Scavia et al., 2002). Coastal areas, like those in San Diego County, are especially vulnerable to climatic effects, such as sea level rise and coastal erosion. As a result, coastal communities in particular are pressed to find ways of adapting to face these threats.

These impacts will primarily affect the young and future generations which necessitates that youth have a clear and comprehensive understanding of the science of climate change and be motivated to take action (Hu & Chen, 2016). Students should be knowledgeable about the mechanisms of climate change and the ways we can mitigate the impacts and adapt accordingly. In fact, the current Next
Generation Science Standards framework identifies climate science and human impacts as key scientific ideas that all students should learn by the end of high school (National Research Council, 2012). However, science textbooks often do not adequately address students’ misconceptions about climate change, and students do not gain a full understanding of the scientific or social implications of climate change (Choi et al., 2010). Furthermore, speaking about climate change in the abstract, without relating it to students’ personal experiences, may not be enough to engage students in a way that encourages action.

Barriers to students’ active engagement in responding to climate change include: students may have an incomplete understanding of the subject, textbooks may not address their held misconceptions about climate change, and perceptions that global climate change is irrelevant at community scales (Hu & Chen, 2016). In order to create a more meaningful learning experience for students on the subject of climate change and subsequently to encourage action, it is necessary to communicate that climate change does have impacts on local scales.

One way of achieving this awareness is to engage students in place-based education. According to Nichols et al. (2016), place-based education “emphasizes experiential, active, and genuine learning, which increases academic engagement and achievement and a sense of belonging to a community.” A place-based education pedagogy suggests that relating lessons to the students’ lived experiences and their shared community will allow for a more meaningful education experience. While many teaching strategies promote scientific literacy, skills, and positive attitudes, a place-based education approach can ultimately increase environmental stewardship behaviors because students who know and care about the environments in which they live are more likely to want to protect them (Hu & Chen, 2016). Because climate change impacts will be increasingly felt if we carry on with business as usual, especially by young and future generations, today’s school students must be prepared to address current and future challenges.

In recognizing the need to increase the climate science literacy of high school students, I developed a curricular unit to address the subject, and piloted the curriculum with a tenth-grade Chemistry class at High Tech High North County. The unit is comprised of three lessons covering the causes, effects, and potential solutions in addressing climate change. To leverage the benefits of place-based education, I focused on climate change as it relates to students and their communities in San Diego County. The community-centered approach of this unit naturally led to my collaboration with a local conservation organization, WILDCOAST. WILDCOAST’s mission - to conserve coastal and marine ecosystems and wildlife - aligns perfectly with my own goals in teaching students about the effects of climate change and what we together can do to find solutions to this problem. Given the location of San Diego County on the coast and the valuable ecosystems found here, it was important that I incorporate discussions of ecology throughout the unit. The lessons were designed to communicate to students that we not only have a great responsibility to protect our coastal and marine ecosystems, but also have the opportunity to use them to our advantage in developing innovative natural climate solutions to adapt to and mitigate the impacts of climate change.
**Current Climate Change Understanding Among Adolescents**

While awareness of climate change is growing within society, much of the public, including teenagers, still lacks a comprehensive understanding of the topic. In 2011, the Yale Project on Climate Change Communication published a report on American teens’ knowledge of climate change. In this study, a total of 517 nationally representative American teens ages 13-17 answered 75 questions relating to the subject of climate change. The goal of this study was to gauge the teenagers’ understanding of “how the climate system works, and the causes, impacts and potential solutions to global warming” (Leiserowitz, Smith, & Marlon, 2011). The study found that only 54% of teens believe global warming is happening and that many misconceptions had led teens to misunderstand the causes, and therefore solutions to climate change (Leiserowitz, Smith, & Marlon, 2011). Furthermore, on a straight grading scale, only 25% of respondents received a passing grade (A, B, or C), and the other 75% received a failing grade (D or F), indicating that relatively few adolescents in the US have a complete understanding of climate change (Leiserowitz, Smith, & Marlon, 2011).

In the past seven years, greater importance has been placed on climate change education, and new research could evaluate whether the results found in Yale’s Climate Change Communication study have changed or improved as a result. Despite this uncertainty in whether climate comprehension has improved in recent years, continuous enhancement of climate literacy among adolescents is an objective that can always be valued and prioritized. An emphasis on climate science education is especially relevant as the impacts of climate change are going to be realized more readily by current students as they age than the decision-making adults of today.

**Challenges to Climate Change Education**

Certainly, a general lack of information on the subject of climate change is a contributing factor to poor climate change literacy among adolescents. However, it is overly simplistic to explain students’ lack of comprehensive understanding and motivation to take action on climate change as being based only within a deficit model – that students simply do not have enough information, and therefore, knowledge on the subject. This explanation is not holistic enough to account entirely for students’ incomplete understanding or general disengagement. This is not to say knowledge is irrelevant or that general knowledge about the processes driving climate change should not be increased, but it is not the only factor influencing students’ perceptions about climate change (Ojala, 2015). Current techniques and frameworks are insufficient, and students’ understanding of climate science is lacking as a result.

As climate change is a worldwide problem, climate science communication and education tend to focus on changes on the global scale (Byg & Salick, 2009). Information presented in this way is less salient and seemingly less relevant to audiences (Byg & Salick, 2009). Long-term climatic data do not influence perceptions as strongly as personal experience (Spence et al., 2011), but traditionally, this is not how climate science is communicated by the media and scientific literature, or taught within classrooms. This disconnect drives one of the most significant reasons people feel apathetic about a
changing climate: the perception that climate change is irrelevant at local and individual scales (Spence et al., 2011; Hu & Chen, 2016). This perception prevents wide and active engagement in pro-environmental behaviors. The reasons for which students deny, ignore, or feel overwhelmed by climate change can be addressed by grounding it in the cultural values and beliefs of the student body, coupled with meaningful experiences in places that hold personal significance. This strategy can both change students’ perceptions about climate change and present a more comprehensive educational experience for students.

**Place-based Education**

Place-based education is not a new concept, but it is one that may have new implications in the way climate change is taught to students. Place-based education is a framework that promotes active, experiential, and genuine student learning within the context of their social, physical and cultural environment (Nichols et al., 2016). This framework can be used to teach many subjects, but has particular significance in environmental education. Creating learning opportunities situated within the learner’s surroundings has been shown to enhance student engagement, stimulate curiosity and importantly, through their investigations, secure commitment to a sense of place (Nichols et al., 2016). Place-based education often incorporates experiential education which allows students to connect with their environment through applied learning and field experiences (Schweizer et al., 2013). Place-based education values students’ personal experiences in the natural environment as well as their learning, social, and cultural environments. Encouraging the development of a strong sense of place and belonging to a community is an important element in the efficacy of place-based education as a pedagogical framework.

Place-based education draws on principles of place-attachment theory which suggests that people have an emotional relationship with specific landscapes (Schweizer et al., 2013). It is on this basis that environmental stewardship can be built. Place attachment can encourage pro-environmental behavior within the context of climate change (Scannell & Gifford, 2010), which means that climate change education must foster emotional engagement to increase behavioral engagement (Hu & Chen, 2016). Furthermore, the development of sense of place has been shown to support collaboration, critical thinking, increased communication skills, heightened creativity, and civic engagement (Nichols et al., 2016). These skills are critical in problem-solving and decision-making which have great importance in enhancing students’ ability to identify and implement solutions to address climate change. Still, students must be motivated to change their behavior in order to realize these potential solutions. This can be achieved by incorporating a place-based educational framework to teach climate science. Place attachment theory shows that people care about protecting the places they find special and significant.

Based on the principles of place attachment theory, developing a place-based education framework to teach about climate change should first provide an opportunity for students to gain a deep sense of belonging and commitment to place. As students’ relationship with their social, cultural, and physical environment grows, it creates opportunity to engage students in the changes occurring within their environment as it relates to climate change. Focusing on the implications of climate
change on the local scale can transform an abstract concept from which students feel far-removed to a more familiar, concrete, and relevant phenomenon (Akerlof et al., 2013). Connecting students to the environment through applied learning experiences in the field increases the likelihood that they will remember the lessons and also adopt new behaviors as they feel an increased sense of responsibility. Students can draw on personal experience, be provided physical and anecdotal evidence, and ultimately witness changes indicating that climate change does have impact on their community to aid in the learning process. By greatly narrowing the scope, the scale is more manageable and students may feel less overwhelmed and paralyzed in finding solutions to climate change.

The benefits of place-based climate change education are two-fold: expanding student understanding and encouraging action. The framework grounds the abstract concept of global climate change in a meaningful context that helps students conceptualize the phenomenon in terms of its local impact and significance on a more personal level. Importantly, lessons learned in a local context can be applied on a larger scale so that students can understand the global impacts of climate change. While focusing learning opportunities on local impacts is important to help learners feel empowered, the scope of lessons can then be expanded so that students understand the gravity of the problem, so long as they are presented in ways that do not instill paralyzing fear or despair (O’Neill & Nicholson-Cole, 2009). It is important to recognize that a single educational experience on the subject of climate change, whether place-based or not, may not produce the lasting effects of engagement and behavioral change needed to address the problem of climate change (Flora et al., 2014). Repeated exposure to lessons on climate change will reveal the greatest and most lasting effects on students’ understanding and therefore behavior. The ways in which students understand and perceive climate change will guide their willingness to take action. Individual action alone is not sufficient to address a problem as large as climate change, and place-based education can help support a willingness to engage in collective action on a greater scale. Structuring climate change education in a place-based framework may allow for a more robust education experience for the students by promoting a sense of place, which will encourage pro-environmental behavior to protect and care for their place.

**Next Generation Science Standards**

Beyond the subject of climate change education alone, there is national recognition that science education as a whole can be improved, and that previous standards for science education have fallen short in creating a strongly scientifically literate population. This led to the development of the Next Generation Science Standards (NGSS).

The overarching goal of the NGSS framework for K-12 science education is to “ensure that by the end of 12th grade, all students have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering and technology” (National Research Council, 2012).
In aiming to achieve this goal, The Committee on a Conceptual Framework for New K-12 Science Education Standards, which is responsible for designing the Next Generation Science Standards, recommends that science education in grades K-12 be built around three major dimensions (National Research Council, 2012). These dimensions are scientific and engineering practices, crosscutting concepts that unify the study of science and engineering through their common application across fields, and core ideas in four disciplinary areas: physical sciences; life sciences; earth and space sciences; and engineering, technology, and applications of science (National Research Council, 2012). This framework has been designed so that students have the opportunity to continue building on and revising their knowledge and abilities over multiple years, and it supports the integration of the knowledge and abilities gained with the practices needed to engage in scientific inquiry and engineering design” (National Research Council, 2012).

Global Climate Change is highlighted specifically as a core idea within the Earth and Space Sciences dimension of the framework. Its inclusion within the NGSS framework along with other core ideas including Weather and Climate and Human Impacts on Earth’s Systems means that students are expected to know about the science behind anthropogenic climate change and how science and engineering can also help address it. The National Research Council states that by the end of grade 12 students should recognize that “the magnitudes of humans’ impacts are greater than they have ever been, [but] so too are human’s abilities to model, predict and manage current and future impacts ... thus science and engineering will be essential both to understanding the possible impacts of global climate change and to informing decisions about how to slow its rate and consequences – for humanity as well as for the rest of the planet” (National Research Council, 2012).

The NGSS framework is being widely adopted, and curriculum is being designed, or redesigned, to meet the standards laid out by the framework. Educators will need materials and resources on the subject of climate change to meet the standard dictated by the framework. I incorporated the NGSS framework into the curriculum I designed for this project so that it will be most readily accessible for teachers to adopt the lessons in their classrooms. Additionally, a place-based education framework can also be integrated into curricula that meet NGSS. This simply involves rooting the three dimensions outlined by NGSS (scientific and engineering practices, crosscutting concepts, and disciplinary core ideas) within a particular place that holds significance for students.

**Impetus for Development**

In recognizing the need to increase climate change comprehension among teenagers, I chose to develop a curricular unit for high school students on the subject. My awareness of the benefits of rooting educational experience in personal experience and place led me to narrow the subject of global climate change to focus on San Diego County. Climate change education is especially relevant in San Diego County as coastal communities will realize additional climate-related impacts that are unique to being situated on the coast, such as sea level rise and coastal erosion.

Educational materials that feature climate change mitigation and adaptation strategies that are being used nationally, and even globally, are abundant. However, there is a stark lack of educational
resources that included the importance of natural climate solutions in promoting climate change resilience. Students often speak of the importance of renewable energy and public transportation in mitigating climate change. But again, in trying to maintain a place-based focus, I sought to find educational materials that highlighted climate solutions unique to San Diego County, and coastal communities such as ours. Incredible ecosystems in San Diego County, including those found within the 11 Marine Protected Areas or MPAs throughout the county, and I wanted to highlight their value in providing and enhancing climate change resilience.

San Diego is well-situated to employ natural climate solutions, such as coastal ecosystem restoration, by optimizing the existing natural infrastructure. Noticing the lack of resources featuring natural climate solutions over the more widely recognized solutions such as renewable energy, I developed the unit to specifically focus on the ways in which communities in San Diego County can utilize existing natural infrastructure. A focal point of these lessons is the benefit Marine Protected Areas (MPAs) in San Diego County provide in terms of natural climate solutions. California’s network of MPAs was established in an effort to protect the valuable marine and coastal ecosystems through implementation of ecosystem-based marine spatial management plans. This has had many positive effects including the often-touted benefits of increased productivity and biomass within the MPAs and enhanced recreation value (Dixon, 1993). Often overlooked is the ability MPAs to offer climate change mitigation and adaptation solutions. For example, the submerged aquatic vegetation such as seagrass and kelp found in MPAs sequester carbon from the atmosphere (Fourqurean et al., 2012). The restoration and protection of marine vegetation within MPAs may be used as a tool in climate change mitigation. I chose to make this a key component of the unit because MPAs have tremendous value, including enhancing climate change resiliency, but are often left out of the climate change conversation.

Ultimately, I designed this curriculum with the goal to educate students on the causes, effects, and solutions in addressing climate change, and in doing so increase the stewardship capacity of young people in San Diego County.

Applications

In order to create a curriculum that would be of actual use, I collaborated with the local conservation organization WILDCOAST. As a community-based organization committed to conserving and sustaining coastal and marine ecosystems and wildlife, WILDCOAST is dedicated to engaging multicultural youth and their families in conservation work to improve the quality of life where they live. WILDCOAST works with schools, youth groups, and tribal communities to inform and educate about the wild places in San Diego County, inspire a sense of stewardship to care for these places, and engage young people in the dialogue surrounding coastal and marine conservation.

Given WILDCOAST’s involvement in education and outreach throughout San Diego County, it was both fitting and mutually beneficial to collaborate on this project. Specifically, I envision that this unit will support their Floating Lab field activity, which was incorporated as a component of this project as it was piloted. Integration of my work into the Floating Lab experience will involve providing teachers
with the curriculum and resources to teach the material in their classrooms prior to, and following, their class’ participation in the Floating Lab. Teachers who are chosen or elect to participate in WILDCOAST’s Floating Lab will be offered the curriculum to use, and by incorporating the material into their lessons will provide students a greater understanding of the significance of coastal and marine environments as they teach a science curriculum.

In addition to its availability as a supplement to the Floating Lab, my curriculum will be able to be more widely used as it is included as a resource within “teacher toolkits” developed by the San Diego Marine Protected Area Collaborative. Each teacher toolkit contains educational resources about MPAs. WILDCOAST and other organizations are contributing a variety of materials which include classroom posters, lesson plans, materials for distribution, digital materials, physical games among other tools to enhance the MPA learning experience in the classroom.

A total of 100 toolkits will be distributed throughout San Diego County, 90 to school teachers and 10 to docents in the area. This will greatly expand the reach of my work and will hopefully engage more young people in conservation initiatives and environmental stewardship. Because it is aligned with the Next Generation Science Standards, my curriculum is already appropriately developed to be integrated into classrooms. The inclusion of the curriculum within the toolkits will broaden the capacity of teachers to educate their students about coastal conservation and climate science.

The Curriculum

Development:

To address the problem of insufficient place-based climate change curriculum I created a unique unit covering the subjects of climate change and coastal ecosystems, highlighting their connectivity. In developing the lessons, I drew from the Science and Policy of Global Climate Change Curriculum Unit produced by the Stanford Climate Change Education Project. I also looked to the educational materials created by the Climate Science Alliance (CSA), including the Climate Kids Oceans curriculum, in an effort to maintain language and messaging consistency. As students in San Diego County may have previously engaged in CSA programming, or will in the future, I hope that by keeping the language between CSA curriculum and my own consistent, repeated exposure to these concepts will enhance their comprehension and increase the likelihood of positive engagement.

Drawing from existing curricula helped me create a more thorough and comprehensive series of lessons myself. Much of the content is completely original, of my own creation and design. This is largely because there exists little educational material that focuses on the connectivity of climate change and coastal ecosystems specifically, as compared with other climate-related topics. Though there is peer-reviewed literature on this subject, it has not been widely incorporated into lessons designed to educate school-aged students.

Each lesson I created follows the BSCS 5E Instructional Model teaching approach. A 5E lesson guides students through five phases of learning: Engagement, Exploration, Explanation, Elaboration, and
Evaluation. Developed as a research-based instructional model which would guide educators’ approach to instruction in a meaningful way that would enhance student learning, the 5E model has been used widely, and successfully, since the late 1980s (Bybee et al., 2014). The following table, excerpted from The BSCS 5E Instructional Model: Origins and Effectiveness report, outlines the sequential phases of a 5E lesson (Bybee et al., 2006).

<table>
<thead>
<tr>
<th>Phase</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engagement</td>
<td>The teacher or a curriculum task accesses the learners’ prior knowledge and helps them become engaged in a new concept through the use of short activities that promote curiosity and elicit prior knowledge. The activity should make connections between past and present learning experiences, expose prior conceptions, and organize students’ thinking toward the learning outcomes of current activities.</td>
</tr>
<tr>
<td>Exploration</td>
<td>Exploration experiences provide students with a common base of activities within which current concepts (i.e., misconceptions), processes, and skills are identified and conceptual change is facilitated. Learners may complete lab activities that help them use prior knowledge to generate new ideas, explore questions and possibilities, and design and conduct a preliminary investigation.</td>
</tr>
<tr>
<td>Explanation</td>
<td>The explanation phase focuses students’ attention on a particular aspect of their engagement and exploration experiences and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviors. This phase also provides opportunities for teachers to directly introduce a concept, process, or skill. Learners explain their understanding of the concept. An explanation from the teacher or the curriculum may guide them toward a deeper understanding, which is a critical part of this phase.</td>
</tr>
<tr>
<td>Elaboration</td>
<td>Teachers challenge and extend students’ conceptual understanding and skills. Through new experiences, the students develop deeper and broader understanding, more information, and adequate skills. Students apply their understanding of the concept by conducting additional activities.</td>
</tr>
<tr>
<td>Evaluation</td>
<td>The evaluation phase encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate student progress toward achieving the educational objectives.</td>
</tr>
</tbody>
</table>

Content:

The curricular unit I developed is comprised of three lesson plans, a laboratory experiment, and a field experience. By including a variety of activities, this unit meets the standards of a 5E lesson plan, NGSS, and serves a student population of diverse learners. This unit focuses on scaffolding lessons the first of which introduces the subject of climate change, and subsequent lessons expand on the subject matter to cover how climate change is affecting coastal communities in San Diego, and what we can do to address the problem of climate change. All lesson plans are included in the Appendix of this report.
The first lesson entitled *The Science of Climate Change* (Appendix A) introduces the science of climate change covering the Earth’s energy balance, the mechanisms of the greenhouse effect, and the driving forces behind climate change. At the end of this lesson, students should be able to distinguish the features of weather and climate and express how an anomalous weather event does not provide empirical evidence for or against climate change. They should also be able to explain the elements of climate and analyze the earth’s energy balance that affects climate change, and identify the causes of climate change as well as the evidence for these causes.

The second lesson, *The Consequences of Climate Change*, (Appendix B) demonstrates how climate change is impacting society at global and local scales. This lesson focuses on climate change impacts on coastal and marine ecosystems in San Diego County. The primary learning outcome of this lesson is students’ ability to analyze the impact of climate change on physical and biological systems, recognizing impacts that will most affect coastal communities, like those in San Diego County. Students will also recognize the connectivity within a watershed and understand that even inland communities are connected to and influence coastal and marine ecosystems. Finally, students will be able to explain what an MPA is and locate MPAs near their community.

The third lesson in the unit is titled *Achieving Climate Change Resilience* (Appendix C) and focuses on how the impacts of climate change discussed in the previous lesson can be addressed through mitigation and adaptation strategies. This lesson highlights employing natural climate solutions in climate change adaptation. Following this lesson, students should be able to recognize the risks and problems society faces as climate change impacts are anticipated and realized and be able to offer solutions to address these impacts. Students should be able to compare and contrast climate change adaptation strategies in light of environmental, financial and social impact, and students should recognize the importance and benefit of employing natural climate solutions as climate adaptation strategies.

**Teaching**

By connecting and collaborating with a Scripps Institution of Oceanography alumna and high school Chemistry teacher, Johnnie Lyman PhD, I had the fortunate opportunity to pilot my project by teaching my lessons to a class of tenth-grade students at High Tech High North County. In total, there were 47 students divided into two class periods of about 24 students each. As in any classroom, the backgrounds, abilities, and learning needs of the students were very diverse. There were several non-native English speakers in each class. High Tech High follows a full-inclusion classroom model and students of all learning abilities are present in the classroom together. This kind of student population lends itself well to group work, and each lesson included a collaborative group activity.

I visited the school on five separate occasions to teach. On the first day, I introduced myself and the work the students and I would be doing together. Over the next four visits, I taught my lessons and facilitated group activities over a two-hour time block. During my time with the students, we established a positive working relationship in which we learned and grew together.
Perhaps the most valuable and certainly the most memorable part of this lesson for students was their participation in a field experience appropriately named a Floating Lab with myself, their primary teacher, and the outreach specialists at WILDCOAST. During the Floating Lab students joined WILDCOAST staff on a boat which departed from Seaforth Landing in Mission Bay, San Diego, and traveled to the South La Jolla State Marine Reserve, one of San Diego County’s 11 MPAs. Once in the MPA, students conducted a plankton tow, took water samples, and conducted an MPA Watch survey. The data collected by students are shared with Scripps Institution of Oceanography, MPA Watch, and a water sample is contributed to the California Department of Public Health.

The Floating Lab was a critical component in this unit in that it allowed students to make a real, tangible, and experiential connection between the material we had covered in class and their lived experiences in San Diego County. This experiential element was essential in rooting this unit in a place-based framework that highlights the relevance of information learned in class within the greater context of students’ physical environment outside the classroom. The Floating Lab provided students the opportunity to see first-hand the ecosystems we had studied in class and make a connection with wild, open spaces in their community.

Results

I developed a summative assessment (Appendix E) that was administered to students both prior to and following the lessons. The questions on the assessment were kept identical each time it was administered, offering a way to quantify student comprehension and knowledge. The assessment consisted of:

- multiple choice questions with only one correct answer
- questions that asked students to select all of the correct answers in a given list
- questions that asked whether the information was true or false
- open response/short answer questions
- questions about students’ prior personal experiences

Of these questions, only those with an objectively right or wrong answer (multiple choice, select all that apply, true/false) were included in the statistical analysis of students’ grades. The total number of possible points was 26.

A paired-samples t-test was conducted to compare pre-lesson assessment scores and post-lesson assessment scores. There was a significant difference in the scores for the pre-lesson assessment (M=15.5, SD=4.32) and the post-lesson assessment (M=18.3, SD=4.61) conditions; t(35) = -4.707, p = 0.0000388. These results show that students’ scores improved after having received the lessons. Before the lessons, students scored an average of 59.6% and after the lessons, scores averaged 70.4%, an improvement of 10.8% (Fig. 1). Higher scores indicate greater knowledge and understanding, and because of the statistical significance in these results it can be concluded that students did gain knowledge as a result of having been presented with the lessons.
Furthermore, it is important to note that the improved assessment scores are not the only way to gauge student learning. Though less quantitative, the answers the students provided in a feedback survey (Appendix #) about their biggest “take away” message at the end of the unit qualitatively reflect positive results of piloting the curriculum. Of the 40 students surveyed, eighteen included the term ‘climate change’ in their response, and an additional four students either used the term ‘global warming’ or implied that they were writing about climate change. Four students cited MPAs as the most important subject they learned about. One student wrote about both MPAs and climate change and her response was tallied in each category.

Below, I have included some of the most compelling responses, which qualitatively indicate student engagement with the curriculum and positive results overall. When I set out developing this curriculum, I wanted to include three main components: maintain a place-based focus within San Diego County, highlight natural climate solutions as mitigation and adaptation strategies, and engage students in a way that encourages action. When asked “what is the most important thing you learned?” student responses yielded these answers:

“Sea level rise is directly impacting our local areas.” – Caleb C.
“There are natural solutions to climate change like planting coastal vegetation, restoring salt marshes, etc.” – Sasha R.

“Even though I’m just a teenager, there is still something I can do to make small differences when it comes to climate change. That is the most important thing I learned.” – Mercedes D.

More than test results, I believe these candid student responses are a clear indicator that my personal goals in designing this curriculum were achieved.

**Overall Success**

The results demonstrating improved scores between assessments taken before and after the lessons are one measure of success, as are the responses students provided in the feedback survey. The act of piloting this curriculum and the improved scores indicate another measure of success – proving its efficacy as a tool available to teachers and the outreach specialists at WILDCOAST. Its applicability as a practical and useful curriculum has been a goal of this unit, and its application within the classroom marks its benefit and success.

WILDCOAST’s intention to use the unit developed in this project to enhance the overall educational experience that is promoted by the Floating Lab speaks to its value as a tool for climate change education. These lessons and the Floating Lab bolster each other, and neither the in-class experience nor the field experience are as holistically educational if they independently stand alone. It is specifically the background information about climate change and coastal ecosystems that is presented in the classroom that provides an important basis of knowledge that makes the field experience so engaging and impactful. Similarly, without going on a boat into an MPA, the lessons alone would not seem as personally relevant nor would they secure students’ sense of place to the area.

It is important to note here that prior to Floating Lab, students were asked in the pre-lesson assessment whether they had previously been to an MPA. Eleven students responded ‘yes’, four students responded ‘no’, and 21 students indicated that they did not know. In the post-lesson assessment, 33 students replied ‘yes’, and only three students said ‘no’. After the lessons, no student said they did not know whether or not they had been to an MPA. With place-based education as a focus of the unit, it is important to recognize students’ engagement in the natural environments in their community, in this case an MPA, as a success.

Furthermore, the curriculum’s incorporation within the teacher toolkits developed by the San Diego MPA Collaborative will increase the scale of reach for this particular project. More than just the students who participate in WILDCOAST’s Floating Lab, teachers and students throughout the county will have the opportunity to use and learn from this curriculum. By engaging more students in more classrooms, I hope this curriculum will continue to yield positive results and engage more young people in conservation initiatives and environmental stewardship.
Feedback

I developed a questionnaire (Appendix D) for the students to complete so that they could provide feedback about what they found were the most effective and least effective parts of the unit. They also had the opportunity to offer suggestions about how to improve the lessons in the future. Students were instructed to provide feedback that is kind, helpful, and specific. I asked that they be honest and constructive in the way they answered the questions. The questions I asked were:

1. What was your favorite part about this unit? Why?
2. What was your least favorite part? Why?
3. What was your biggest “take-away”? What was the most important thing you learned?
4. What do you still have questions about? Is there anything we discussed that you still do not feel you understand completely?
5. What do you suggest I change to improve this lesson in the future?

I received 40 completed surveys, as not all students were present on the last day of class.

Not surprisingly, more than half of the students cited the Floating Lab as their favorite part of the unit. Students provided a variety of reasons why they considered this their favorite part. Most in some way indicated that the hands-on nature of the Floating Lab made the activity particularly effective and enjoyable. Other reasons cited include: gaining perspective on the work conservation organizations like WILDCOAST do, having the opportunity to collect data, dissecting squid, getting out of the classroom for a day, and the experience of being on a boat for the first time. I was pleased to see that of the 23 students who cited the Floating Lab as their favorite activity, four specifically mentioned that going to an MPA made it especially meaningful for them. I believe this speaks to the importance of place-based education, especially when it involves actively engaging students in their physical environment outside the classroom.

Few students had any lingering questions and most said that they felt they understood the material well. The students’ answers about what they considered the most important concepts they learned vary. Their feedback is expounded upon in the Measures of Success portion of this report.

In my opinion, the most valuable feedback I received was about what the students did not enjoy about the lessons and their suggestions to improve the unit. Twelve students wrote that the lectures were their least favorite part of the unit. More importantly, 23 students wrote that the unit could be improved by incorporating additional activities or substituting lectures for activities. Specifically, the students suggested that activities be interactive, engaging, and hands-on, and explained that they would learn more effectively by doing rather than being presented with the material in a teacher-centered lecture.

This feedback is well-received, and I will incorporate the student suggestions into future revisions of this unit. I believe that the high percentage of students recommending more activity-based learning is a reflection of the environment in which I was teaching. High Tech High is guided by four connected design principles—equity, personalization, authentic work, and collaborative design. Students typically work on hands-on, minds-on projects to learn new concepts and material. It is infrequent that they are taught via lecture or PowerPoint presentations. Though students in traditional schools
may be more comfortable and familiar with lecture-style learning, this does not mean that it is the best method for promoting student comprehension. The students at High Tech High North County may have the right idea that incorporating inquiry-based activities will best pique their interest, engage their curiosity, and teach the material in a way that is relevant, meaningful, and memorable.

**Lessons Learned**

As a result of the student feedback, the greatest lesson I learned in developing and teaching this curriculum is the importance of incorporating hands-on activities as a teaching and learning tool. Based on my observations and interactions with the students, student-centered, inquiry-based learning seems to have the most positive impact on student learning and engagement.

Student-centered learning also presents a challenge for teachers, like myself in this instance, whom are not intimately familiar with the abilities of students and the prior knowledge they bring with them to class. Realizing that I did lack this understanding of student ability, I thought that it might be best to introduce the material in a lecture-style slideshow presentation. I had assumed that this would help get all the students “on the same page” so to speak. However, in the feedback survey, several students said that the presentations were not engaging and that they easily lost focus. This is unsurprising as studies have shown that students in a lecture setting alternate between being engaged and non-engaged, experiencing lapses in attention in ever-shortening intervals (Bunce, Flens, & Neiles, 2010). By involving students more actively in the learning process, it may result in greater student engagement and meaningful learning.

I believe this will present less of a challenge in future applications, because this curriculum will be distributed to teachers who will use it within their own classrooms as a basis and guide in teaching the subjects of climate change and coastal ecosystems. These teachers will likely be aware of any limitations their students may face in learning the material. Teachers should review the material within the curriculum before presenting it to students, because although it is designed for high school, some components may need to be adapted to be appropriate for different grade levels.

Acknowledging the need to adapt materials in this way was another lesson I learned. Some of the students I taught were non-native English speakers, and often struggled with some of the vocabulary in the lessons. This is likely to present a challenge in classrooms throughout San Diego County, as there is a significant population of English language learners here. Alternative reading materials that are better suited to different reading comprehension levels should be made available so that all students can engage in the lessons and activities in a way that is most effective for them.

**Extensions and Future Applications**

In order to be the most effective and successful moving forward, ongoing revisions will be made that reflect student and teacher feedback. Furthermore, this unit should be tailored to best meet the needs of different user groups.
This unit is designed to be taught within San Diego County, however, it may be adapted to offer a place-based framework in other coastal cities. The examples and scenarios used in these lessons can easily be changed to feature other coastal communities, as the problems of sea level rise and coastal erosion are threatening low-lying coastal cities across the globe. In fact, the San Diego County MPA Cooperative and the California Department of Fish and Wildlife suggested that this curriculum may be suited for adaptation to be included in teacher toolkits in other counties throughout California.

While this curriculum will ideally be used as a framework within which the Floating Lab activity fits, enhancing the overall learning experience, some schools and teachers may not have the time or capacity to include an entire three-lesson unit in addition to the field experience. In this case, I can synthesize the most important and salient points about climate change and coastal ecosystems from each lesson and incorporate these concepts within the Floating Lab as it is currently designed. Students will gain the greatest understanding from a full unit of instruction, but that is not to say that introducing ideas about climate change and its impact on coastal and marine environments will not have a positive educational impact. This is especially true when such ideas are incorporated during an impactful field experience that encourages students to care for the wild spaces in their coastal community.

**Conclusion**

The curriculum developed in this project represents a beneficial and useful teaching tool for educating high school students about the subjects of climate change and coastal ecosystems. The delivery of the lessons to students resulted in higher scores on a summative assessment by an average of 10.8%, indicating that the curriculum is an effective way to educate students. This presents incentive for teachers to integrate this unit within their own curriculum, and is a way to meet the Next Generation Science Standards on the subject of global climate change.

It is of critical importance that the students in grades K-12 today are educated on the causes and effects of climate change and the ways to address them. It is necessary that education prepares students today for the inevitable impacts that will be felt in the future and provides them the tools to find solutions in mitigating and adapting to a changing climate. An education that provides students a sense of place and illustrates the importance of protecting that place may encourage the meaningful engagement of students not only in the learning process but also in becoming inspired to act. With an educated and empowered body of students motivated to take action, there is hope for our planet yet.
References


Rodger Bybee, B. W., Landes, N., Ellis, J., Carlson, J., Muscella, D., Robertson, W., ... Foster, G. (2014).


# The Science of Climate Change

**Level:** High School  
**Topic:** Earth and Space Science  
**Lesson # 1 in a series of 3 lessons**

## Lesson Description:
An introduction to the science of climate change covering the Earth’s energy balance, the mechanisms of the greenhouse effect, and the driving forces behind climate change.

## Performance Expectation(s): 
- Ask questions about the natural and human built-worlds: for example, how are greenhouse gases created? 
- Plan experimental procedures, identifying relevant independent and dependent variables, and when appropriate, the need for controls. Consider possible confounding variables or effects and ensure that the investigation’s design has controlled for them. 
- Discuss the limitations and precision of a model as a representation of a system, process, or design and suggest ways in which the model might be improved to better fit available evidence or better reflect a design’s specifications. Refine a model in light of empirical evidence or criticism to improve its quality and explanatory power. 
- Recognize patterns in data that suggest relationships worth investigating further. Distinguish between causal and correlational relationships.

## Specific Learning Outcomes: 
- Students will be able to distinguish the features of weather and climate and express how an anomalous weather event does not provide empirical evidence for or against climate change. 
- Students will be able to explain the elements of climate and analyze the earth’s energy balance that affects climate change. (What is climate change?) 
- Students will be able to identify the causes of climate change as well as the evidence for these causes. (What is responsible for climate change and how do we know?)

## Narrative / Background Information

### Prior Student Knowledge: 
- Students should know that the Earth is comprised of many connected systems (atmosphere, hydrosphere, geosphere, biosphere, cryosphere) that make the planet inhabitable. 
- Students should be familiar with the way Earth moves through space and understand that Earth’s tilt on its axis affects the amount of solar radiation different places receive. 
- Students will have heard about climate change, but may have incomplete thoughts and understanding or received information from a non-scientific source.

## Science & Engineering Practices: 
- Asking Questions and Defining Problems 
- Planning and Carrying Out Investigations 
- Analyzing and Interpreting Data 
- Developing and Using Models

## Disciplinary Core Ideas: 
**ESS2: Earth’s Systems** 
ESS2.A: Earth Materials and Systems 
ESS2.D: Weather and Climate  
**ESS3: Earth and Human Activity** 
ESS3.C: Human Impacts on Earth Systems 
ESS3.D: Global Climate Change

## Crosscutting Concepts: 
- Cause and Effect: Mechanism and Explanation 
- Systems and System Models 
- Energy and Matter: Flows, Cycles, and Conservation 
- Stability and Change
Possible Preconceptions/Misconceptions:

- Students may confuse weather and climate
- Students may misconceive that climate change is the result of the hole in the ozone layer
- There may be climate change denial

**LESSON PLAN – 5-E Model**

1. **ENGAGE: Access Prior Learning**

   - Teacher will administer pre-lesson assessment to gauge students’ prior knowledge on topics to be covered in this unit: The mechanisms of climate change, the effects of climate change, coastal ecosystems, marine protected areas, and mitigation/adaptation/resiliency
     - This pre-lesson assessment can be administered again at the end of the unit as a summative assessment
   - Ask students what they know, think, and feel about climate change -
     - Where do they hear about climate change?
     - By raising their hands and displaying their fingers, how worried are they about climate change?
       (1 meaning I’m not worried at all, 5 meaning I’m extremely worried)

2. **EXPLORE: Lab activity** Choose an item:

   **Greenhouse in a Jar Lab**

   - This lab is designed to get students thinking about the heat-trapping effect of atmospheric carbon dioxide (the greenhouse effect)
   - By designing this activity as an inquiry-based lab, students are called upon to use the NGSS Science Practice of Planning and Carrying Out Investigations by constructing their own experiment to develop and use a model demonstrating the heat-trapping effect of greenhouse gases.
   - Students should begin considering in what ways this model represents a system similar to the Earth and its atmospheric processes.
   - Questions to encourage and focus students’ exploration:
     - What variable is responsible for producing the difference in temperature between the two bottles?
     - What would happen if we added more of that variable? (Alka-seltzer which produces CO2)
     - How is CO2 being produced every day outside of this experiment?
     - What effect does that have on the temperature of the air within Earth’s atmosphere?

3. **EXPLAIN: Concepts Explained and Vocabulary Defined: Digital Presentation**

   **Description:**

   - A PowerPoint presentation takes students through the mechanisms driving climate change.
     - Throughout the presentation, the teacher will encourage student participation by asking higher-order thinking questions. Students should be prepared to explain their answers and justify these explanations.
     - Questions may include: What relates weather and climate? Why is the climate system important? Do the graphs in this accurately represent the data and show a full picture?
   - Students are asked to interpret data from graphs
   - A video helps explain how scientists measure atmospheric CO2, how we know CO2 concentrations are rising, and why it matters.
     - It should be pointed out that the video is shot at Scripps Institution of Oceanography, a local and familiar institution for students in San Diego, but a world-leader in oceanic and atmospheric science
   - The greenhouse effect is compared to a heat-trapping blanket to help students understand the way greenhouse gases retain radiated energy and warm the atmosphere. The heat-trapping blanket analogy is consistent with climate change messaging from NNOCCI and Climate Science Alliance, reinforcing these concepts across different platforms.
**Vocabulary:** Student explanations should precede introduction of terms or explanations by the teacher. Students may be asked to provide examples they recognize in their personal lives.

- **Weather** - the day-to-day state of the atmosphere, and its short-term variation in minutes to weeks
- **Climate** - the composite or generally prevailing weather conditions of a place averaged over a period of time, often 30 years.
- **Radiation** - the process in which energy is emitted by one body, transmitted through an intervening space or medium and absorbed by another body
- **Greenhouse gas** – a gas that can absorb infrared radiation in the atmosphere. Examples include carbon dioxide, methane, nitrous oxide, chlorofluorocarbons, water vapor and ozone
- **Greenhouse effect** - the warming of the earth's atmosphere that occurs when the sun's radiation passes through the atmosphere, is absorbed by the earth, and is given off as radiation of longer wavelength which can be absorbed by atmospheric gases (as carbon dioxide and water vapor)

4. **ELABORATE:** Applications and Extensions: Students will journal

**Description:**
- Ask students to reflect on how we as a society and how we as individuals contribute to global climate change.
- Instruct students to take a moment to write about these questions:
  - Do you think we, as individuals, have a responsibility to change our behavior? As a state? A nation? A planet?
  - Do you think that you personally can make a difference? Why or why not?

5. **EVALUATE:** Discussion

**Formative Monitoring (Questioning / Discussion):** Ask students to think about these questions, discuss their ideas with a partner, then ask them to share with the class for group discussion.
- How did our lab show how greenhouse gases work?
- What was accurate about this model?
- What did this model leave out?
- Are there ways we can change it to be more representative of Earth’s atmospheric system?

**Elaborate Further / Reflect: Enrichment:**
As an extension of this lesson, students can calculate their own carbon footprint.
Question: How does the presence of increased levels of CO₂ affect the temperature inside a bottle when exposed to heat?

You are designing an experiment that will test the effect of carbon dioxide on the temperature of the atmosphere (air) within a closed system.

Discuss with your group different ways to set up the lab. Decide on a lab set up as a group.

Materials
- 1L soda bottles
- thermometers
- Alka-seltzer tablets
  (a chemical reaction occurs when the alka-seltzer tablet is placed in water. When introduced to water, sodium bicarbonate and citric acid in the tablet react, producing carbon dioxide)
- A heat source (light bulbs and heat lamp)

You will have access to other materials you may want to use in your experiment set up, like tools for measuring (beakers, ruler, stopwatch, etc.) and tools for securing materials in place (string, tape, tin foil, etc.)

Diagram of experimental set up
What data will you need to collect? How will you collect these data?

Written procedure (the steps you will take to perform this experiment)

Hypothesis: What do you think will happen?
The Consequences of Climate Change

<table>
<thead>
<tr>
<th>Level: High School</th>
<th>Topic: Life Sciences and Earth Systems</th>
<th>Lesson # 2 in a series of 3 lessons</th>
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</table>

**Brief Lesson Description:** Following a lesson on the science of climate change, this lesson will demonstrate how climate change is impacting society not only at global, but also at local scales. This lesson focuses on climate change impacts on coastal and marine ecosystems in San Diego County. Students will be introduced to Marine Protected Areas (MPAs) as a spatial management tool.

**Performance Expectations:**
- Ask questions about the natural and human-built worlds: for example, how is human-induced climate change affecting ecological systems?
- Read scientific text, including tables, diagrams, and graphs, commensurate with their scientific knowledge and explain the key ideas being communicated
- Recognize the major features of scientific writing and be able to produce written and illustrated text and oral presentations that communicate their own ideas and accomplishments

**Specific Learning Outcomes:**
- Students will be able to analyze the impact of climate change on physical and biological systems, recognizing those that will most affect coastal communities, like San Diego. This will include climate change impacts on biodiversity.
- Students will recognize the connectivity within a watershed. Students will learn that even inland communities are connected to and influence coastal and marine ecosystems.
- Students will be able to explain what a Marine Protected Area is and locate MPAs in their community.

**Narrative / Background Information**

**Prior Student Knowledge:**
- Students will have been introduced to the science of climate change in a previous lesson in this unit
- Students should have already learned about habitats and ecosystems.
- Students will have their own personal experiences that inform and enhance their understanding of ecoregions in their community.

**Science & Engineering Practices:**
- Asking questions and defining problems
- Obtaining, evaluating, and communicating information

**Disciplinary Core Ideas:**
- LS2.C – Ecosystem Dynamics, Functioning and Resilience
- LS4.D – Biodiversity and Humans
- ESS2.C – The Role of Water in Earth’s Surface Processes

**Crosscutting Concepts:**
- Scale, Proportion, and Quantity
- Stability and Change
- Cause and Effect: Mechanism and Explanation

**Possible Preconceptions/Misconceptions:**
- Students may think that climate change is not relevant on small scales that can have impacts on their communities.
- Students may believe that climate change is a more distant problem that we do not need to actively address now.
- Students may not have previously considered the connectivity between ecological systems, or their influence/impact on these systems.
**ENGAGE**

Description of ENGAGE Opening Activity:

- As a class, we locate ourselves on a map. Starting globally, and continuing on increasingly smaller scales, students will mark with a pushpin the community in which they live.
- Students may also be shown two short videos. Both are produced by WILDCOAST. The first offers an introductory primer on Marine Protected Areas. [https://www.youtube.com/watch?v=gSE9SdtW-po](https://www.youtube.com/watch?v=gSE9SdtW-po) The second video gives a little “sneak peek” of the Floating Lab project students will participate in as an extension of this lesson. [https://www.youtube.com/watch?v=bL1joIpHaU](https://www.youtube.com/watch?v=bL1joIpHaU) This video may also, or alternatively, be shown, which is a combination of the first two highlighting both the importance of MPAs and the Floating Lab project [https://www.youtube.com/watch?v=zjcLTL_cNB0](https://www.youtube.com/watch?v=zjcLTL_cNB0)

**EXPLORE**

Lesson Description – Materials Needed / Probing or Clarifying Questions:

- Following the mapping activity, the teacher will offer a quick review of climate change and the greenhouse (heat-trapping blanket) effect.
- Students will work in groups to brainstorm climate change impacts. Each group will be given a broad impact of climate change and be asked to think of as many consequences as they can that will result from or relate to that impact. Each group will be asked to list impacts related to one of these broad categories: rising atmospheric temperatures, changes in precipitation, and changing ocean conditions.
- Following the mapping exercise and brainstorming activity, students will be primed to think about how the impacts they listed will be realized both globally and locally.
  - Ask students to think about what makes their nation, state, region, county, town special and different from others.
  - What impacts from climate change will affect them most based on where they live?

**EXPLAIN: Concepts Explained and Vocabulary Defined**

Description:

Using PowerPoint, the teacher will discuss what a watershed is and how it functions. Teacher will orient students within their local watershed, emphasizing their connection to the watershed and establishing a sense of place.

- In groups, students will research different ecoregions within their coastal community. Ecoregions to be studied include inland coastal watershed, intertidal/littoral zone, subtidal nearshore, and offshore.
- To guide student exploration and research, we will draw a “map” of the coast from inland to offshore. Students will be given a list of habitats labeled with pictures and be asked to place them in the ecoregion they think it belongs (e.g. kelp forest – offshore, rocky reef - subtidal nearshore, beach – intertidal/littoral)
- Student research should focus on defining:
  - features/conditions of the ecoregion
  - different kinds of habitats that can be found there
  - limiting factors affecting wildlife (how are animals adapted to live there)
  - ecosystem services provided by the ecoregion (how does the ecosystem provide benefits for humans?)
  - the realized and predicted impacts from climate change
- Students will design a poster representing their group’s ecoregion and present the information they have gathered before their classmates
Following the coastal watershed ecoregion research activity, we will discuss Marine Protected Areas (MPAs) as a spatial management tool – a way to manage and protect these ecosystems. Together, we will answer the following questions:

- What is an MPA?
- How do MPAs work?
- Where are our local MPAs? (In our watershed? In our region?)

We can demarcate the MPAs on the map from the first activity.

**Vocabulary:**
- **Watershed** - the area of land where all of the water drains into the same place. Watersheds can be composed of creeks, streams, rivers, ponds, lakes, wetlands, groundwater, and oceans.
- **Ecosystem** – a biological community of interacting organisms and their physical environment.
- **Ecoregion** – areas of similarity in the mosaic of biotic, abiotic, terrestrial, and aquatic ecosystem components with humans being considered as part of the biota.
- **Zonation** – the distribution of plants or animals into specific zones according to such parameters as altitude or depth, each characterized by its dominant species.
- **Marine Protected Area (MPA)** - areas of seas, oceans, estuaries or large lakes which restrict some human activities for a conservation purpose, typically to protect natural or cultural resources. Levels of protection vary between MPAs.

### ELABORATE: Applications and Extensions

**Description: Floating Lab**
- Students will join WILDCOAST staff on a field trip to the South La Jolla State Marine Reserve (Marine Protected Area) via boat.
- Students will form 3 small groups to perform different tasks. One group will conduct a plankton tow, one will collect water samples at different depths, and one will complete an MPA Watch boat-based survey.
- Each group is responsible for collecting data, and recognizing why data collection of this kind is important.

This activity is included within this lesson for several reasons: Having just researched different ecoregions within their watershed, students are primed to

### EVALUATE

**Formative Monitoring (Questioning / Discussion):**
Following the Floating Lab, each group will explain to the rest of the class what they did during the Floating Lab and what data they collected. Each group should express who and why these data are important and how these data can inform us about climate change.

**Summative Assessment (Quiz / Project / Report):**
Group presentations on ecoregions will serve as a summative assessment. Does the group demonstrate and articulate understanding of:

- Habitats and wildlife found in the ecoregion
- Ecosystem services provided
- Climate change impacts that especially affect the ecoregion
Appendix C

Achieving Climate Change Resilience

<table>
<thead>
<tr>
<th>Grade: High School</th>
<th>Topic: Life Science + Earth &amp; Space Science</th>
<th>Lesson # 3 in a series of 3 lessons</th>
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Brief Lesson Description: In this lesson, students will learn how the impacts of climate change discussed in the previous lesson can be addressed through mitigation and adaptation strategies. We will focus on employing natural climate solutions in climate change adaptation.

Performance Expectation(s):
- Solve design problems (of a spatial management plan) by appropriately applying their scientific knowledge
- Identify gaps or weakness in explanatory accounts (their own, or those of others) – evaluate and critique competing design solutions based on jointly developed and agreed-on design criteria
- Construct a scientific argument showing how data support a claim

Specific Learning Outcomes:
- Students will be able to recognize the risks and problems society faces as climate change impacts are anticipated and realized and be able to offer solutions to address these impacts
- Students will be able to compare and contrast climate change adaptation strategies in light of environmental, financial and social impact.
- Students will recognize the importance and benefit of employing natural climate solutions as climate adaptation strategies

Narrative / Background Information

Prior Student Knowledge:
- Students will know what consequences of climate change are anticipated to have global effects
- Students will have particular awareness of climate impacts that will affect coastal cities
- Students will understand what ecosystems and habitats can be found within their watershed and the ecosystem services associated with these ecosystems

Science & Engineering Practices:
- Obtaining, Evaluating, and Communicating
- Engaging in Argument from Evidence

Disciplinary Core Ideas:
- LS2 – Ecosystems: Interactions, Energy and Dynamics
- LS2.C – Ecosystem Dynamics, Functioning and Resilience
- ESS3 – Earth and Human Activity
- ESS.C – Human Impacts on Earth’s Systems

Crosscutting Concepts:
- Cause and Effect: Mechanism and Explanation
- Stability and Change
- Scale, Proportion, and Quantity

Possible Preconceptions/Misconceptions:
- Students may not have considered natural climate solutions as a climate adaptation strategy – they may focus on more “conventional” methods such as renewable energy and reducing the burning of fossil fuels

LESSON PLAN – 5-E Model

ENGAGE

Students will be shown a video addressing what it means to be resilient and the steps necessary to achieve resilience. [https://toolkit.climate.gov/#steps](https://toolkit.climate.gov/#steps)
• Ask students how this can apply to addressing climate change. What can we do to become resilient in facing the impacts of climate change?

**EXPLORE**

Students will explore different case studies of climate change mitigation and adaptation strategies that have been employed across the state of California. Full case study report can be found here: [http://coastalresilience.org/wp-content/uploads/2017/11/tnc_Natural-Shoreline-Case-Study_hi.pdf](http://coastalresilience.org/wp-content/uploads/2017/11/tnc_Natural-Shoreline-Case-Study_hi.pdf)

Students will be divided into groups of four. Each group member will read a different article or case study taking notes on why this strategy was employed and what problem it addressed.

The case studies chosen offer natural climate solutions, which is important to recognize within this unit that focuses on coastal ecosystems in San Diego County. One of the readings is an adapted newspaper article that discusses the pros and cons of using seawalls as a climate change adaptation strategy.

• Guide student reading by asking students to look for the financial, social and environmental costs incurred in their case study.
• Note: these case studies may need to be adapted depending on the grade and/or reading level of students. If the material is challenging for students, instruct the class to read through the material and focus on the big ideas mentioned rather than getting too caught up in the details. The important part is that they understand which adaptation strategy was used in their case study, but not every specific detail about its implementation.

**EXPLAIN: Concepts Explained and Vocabulary Defined**

Students will share with the class the main points from their reading – explaining how and why the climate adaptation strategy in their case study was used.

Climate adaptation strategies featured in the case studies include: managed retreat, dune restoration, establishment of oyster reefs, eelgrass restoration and developing living shorelines. The newspaper article discusses the possibility of seawalls and beach nourishment as adaptation strategies.

• The examples provided by students should be written down on the board because they will serve as adaptation strategies that may be used in the activity that follows.

Teacher will use examples provided by students to show the difference between adaptation and mitigation of climate change. Most of the examples in the case studies are adaptation strategies and teacher should be prepared to give examples of mitigation - such as using renewable energy, increased use of public transportation, carbon sequestration and other activities that reduce the amount of greenhouse gas emissions to the atmosphere.

**Vocabulary:**

• **Mitigation** - the act of making a condition or consequence less severe; lessening the force or intensity
• **Adaptation** - Reacting or changing to fit the new circumstance; coping with impacts that cannot be avoided
• **Resilience** - the ability to recover following disturbance
• **Infrastructure** - the fundamental facilities and systems serving a country, city, or area, as transportation and communication systems, power plants, and schools
  - natural infrastructure – using natural elements like vegetation, wetlands, etc. to provide ecosystem services like flood protection and carbon sequestration
• **Carbon sequestration** - Carbon sequestration is the process involved in carbon capture and the long-term storage of atmospheric carbon dioxide or other forms of carbon to mitigate or defer global warming
• Living shoreline - protected, stabilized coastal edge made of natural materials such as plants, sand, or rock. Unlike a concrete seawall or other hard structure, which impede the growth of plants and animals, living shorelines grow over time.

ELABORATE: Applications and Extensions

Description: Students will participate in a mock City Council meeting
Students will be presented with a scenario in which sea level rise and coastal erosion threaten existing infrastructure, necessitating the development of a management strategy or adaptation plan. In this lesson, students look at Cardiff State Beach as an example where coastal erosion is washing away the beach and flooding occurs on Highway 101 during high tide and storm events.

• Students will continue working in the same group in which they read the case studies. Each group will be given a different stakeholder position to represent. Stakeholder positions include: Homeowners, business owners (Chart House restaurant), recreators (Swami’s Surfing Assoc.), conservation interests (WILDCOAST), and Caltrans which manages the Highway 101.
• Students will be presented with 3 management plans to address the threats impacting Cardiff State Beach and surrounding infrastructure: 1. Full managed retreat 2. A seawall that extends across the entire beach 3. Do nothing to address the problem
• Students will need to argue their stakeholder position, providing reasons and their rationale for choosing their position. Students may include evidence from their case study to support their argument.
• Students will be asked to provide counterarguments to the points made by their classmates and offer reasons for their rebuttal

In this exercise, compromise will be necessary. Using the list of adaptation strategies developed following the reading exercise, students may offer these strategies as alternatives to the management plans proposed.

EVALUATE

Formative Monitoring (Questioning / Discussion): Teacher should try to elicit participation from different members from each stakeholder group to make sure that each student has an understanding of the process and the reasons for which their stakeholder group holds a particular position.

Summative Assessment: This lesson is the last in a three-lesson unit. A post-unit assessment will be administered to gauge student learning and overall comprehension. This assessment is the same as the assessment given at the beginning of the unit. This will inform whether or not student comprehension and understanding increased.

DIFFERENTIATION/MODIFICATIONS

Description: The case studies presented may need to be adapted depending on the grade and/or reading level of students. If the material is challenging for students, instruct the class to read through the material and focus on the big ideas mentioned rather than getting too caught up in the details. The important part is that they understand which adaptation strategy was used in their case study, but not every specific detail about its implementation.
City of Encinitas – Draft Management Plan
Cardiff State Beach

The City of Encinitas is developing a draft management plan to address the problems of sea level rise and coastal erosion that impact Cardiff State Beach and the surrounding areas. As someone who lives or works in the area, you have an interest in how the problem is managed, which makes you a stakeholder. You want your ideas and opinions heard by the city council as they decide how to proceed.

Stakeholder interests that will be represented at city council meetings include homeowners, local businesses (The Chart House restaurant), conservation interests (WILDCOAST), recreators (Swami’s Surfing Association), and CalTrans which maintains Highway 101.

The best management plan is one that will have the most long-term benefits for both the people and the environment. It is impossible to please everyone, so compromise between stakeholders is important.

Use what you have learned in class and the resources provided to argue your stakeholder group’s position concerning the development of a management plan that aims to address the problems of sea level rise and coastal erosion. You must provide reasons and rationale when arguing your position.
Background information on the area:

- Cardiff State Beach (just north of the point labeled Seaside State Beach) is threatened by coastal erosion due to sea level rise.
- Highway 101 handles 20,000 vehicle trips per day.
- Highway 101 has been flooded and damaged in high tide and extreme weather events. Flooding is expected to increase and damage to the highway is likely to worsen due to impacts of climate change.
- Highway 101 was constructed where sand dunes historically existed.
- The parking lot just south of the Seaside State Beach marker is important for coastal access (people can park there to get to the beach), but it is also subject to sea level rise and often floods and fills with sand and sediment.
- Two Marine Protected Areas surround Cardiff State Beach. The San Elijo Lagoon State Marine Conservation Area is to the east of Cardiff State Beach and the Swami’s State Marine Conservation area is to the west, offshore. MPAs prioritize conservation and one of the goals in establishing MPAs is to enhance the recreation value of coastal areas.
For teacher:

The options the City Council has offered are: 1. Full managed retreat, 2. A seawall extending the entire length of Cardiff State Beach or 3. Do nothing to address the issue.

Students must take into consideration the financial cost of the adaptation strategy they recommend.

Option #1 – Full managed retreat: over $1 billion to relocate all homes, business and infrastructure

Option #2 – Seawall: $10 million up front cost to build seawall across the entire beach restored. Costs an additional $500,000 every 10 years for restoration and maintenance

Option #3 – Do nothing: $0 up-front cost - Cost of restorative action/ rebuilding after storms 5 years = $100 million 10 years = $500 million 20 years = $900 million

Other potential solutions that can address the problems may be proposed by students as alternative to the above options. These alternative options should come from the case studies they read earlier in class.

Beach nourishment (sand replenishment) – $1 million every 5 years
Dune restoration - $2 million
Eelgrass bed restoration - $3 million
Oyster reef - $3 million
Relocating the parking lot at Cardiff State Beach - $5 million
Raising the Highway 101 or relocating - $11 million

Values/interests of different stakeholder groups:
- beach access
- recreation (trails, surfing, bird watching, sunbathing, water sports)
- open space
- transportation infrastructure
- property value
- tourism opportunity
- business revenue
- public safety
- wildlife
Home owners

After years of working 18-hour days on Wall Street you now own a beautiful house on West Circle Drive in Solana Beach. Your property value is $6.2 million, but in your opinion, is it essentially priceless because the view is breathtaking, you have spent a lot of time and money on home improvement projects and this is where you raised your children, after all!

Sadly, coastal erosion threatens your precious home as the cliffs it is built upon start to crumble. You will do anything to protect it, and don’t want to move. You like being able to walk down to the beach, but you would rather build a seawall that stabilizes the cliff and allows the sand in front of your home to be washed away than have to move.

Because your property tax is so high, you feel like you should have a say in what the city chooses because a lot of your money is going to whatever project they choose! You don’t mind putting a long seawall across the border of Cardiff State Beach – you think it’s too crowded by tourists anyway.
You are the owner of an upscale restaurant. It is a popular dining location for locals and vacationing visitors alike! The beach front view is the reason many people go to the restaurant, and without it, your restaurant would not be as successful. Sure, your food is delicious, but it is the view that allows you to charge $47 for a dinner entrée.

You recognize that sea level rise is affecting your business because in high tide events the waves crash into the windows of the dining room. But, if you were to move you would lose a lot of business, and you pay a lot of money in property and sales tax to the city. Your ideal option would be beach replenishment (putting sand more onto the beach periodically because it is washing away) and putting in eelgrass beds nearshore to lessen the impact of waves during storm events.
You are a team of passionate ocean-lovers committed to conserving and sustaining coastal and marine ecosystems and wildlife. This means that you prioritize protecting the ecological habitats like those found in the San Elijo Lagoon State Marine Conservation Area and Swami’s SMCA. You work with the California Department of Fish and Wildlife and other conservation groups to manage Marine Protected Areas in San Diego County. In fact, you care about MPAs so much that you are the co-chair of the San Diego Marine Protected Area Cooperative!

You are against putting in seawalls because there are natural alternatives that do less harm to the environment! In fact, you argue that managed retreat and ecosystem restoration is a much better option because it enhances coastal access and recreation opportunity, which is a goal of MPAs.
CalTrans

You may not have the most exciting job, but it is your responsibility to California moving! The mission of CalTrans is to provide a safe, sustainable, integrated and efficient transportation system to enhance California’s economy and livability. That means you take keeping the Highway 101 that runs along the entire coast of California up and running very seriously. The 101 handles 20,000 vehicle trips per day which is hugely important to San Diego’s vitality and function.

You don’t have a strong position on whether seawalls are built or if a natural shoreline is built instead, all you know is that you have a very tight budget and do not have a lot of money to spend on whatever project moves forward. You also cannot keep shutting down the highway because it floods during high tides and storms.
Swami’s Surfing Association Inc. was established in 1964, as a non-profit organization by local surfers for the purpose of support and improving the beach community and supporting environmental issues. You are a founding member of the SSA and known as the “Big Kahuna”. Now, your grandkids are learning how to surf at Swami’s. Your number one priority is making sure you and they have access to the beach and that the waves stay natural and gnarly.

Putting in seawalls is a huge problem for you because it limits access to the beach and makes the waves suck. The awesome waves at Swami’s rely on the natural sand flow of the San Elijo Lagoon and its surrounding watershed. You believe a natural shoreline solution would enhance the wave, but you’d hate to see the Chart House move since you love their Sunday brunch after a killer surf sesh.
Appendix D

Name: ___________________________________________    Date:_______________

1. What was your favorite part of this unit? Why?

2. What was your least favorite part? Why?

3. What was your biggest “take-away”? What was the most important thing you learned?

4. What do you still have questions about? Is there anything we discussed that you still do not feel you understand completely?

5. What do you suggest I change to improve this lesson in the future?
Appendix E

Name: __________________________________________            Date: _____________________

This is a questionnaire designed only to help me understand what you learned from our lessons on climate change and coastal ecosystems. This will not be graded, but will help me structure my lessons to help other students in the future! Please, answer these questions as best you can.

1. The difference between weather and climate is:
a. Weather is what we expect based on years of data while climate is what is happening right now
b. Weather includes more variables like moisture and wind, while climate just focuses on temperature
c. Weather is predictable, but climate is not
d. Weather is a day-to-day event while climate is a consistent pattern over many years

2. Which of these is a greenhouse gas? Circle all that apply.
a. Carbon dioxide
b. Oxygen
c. Nitrogen
d. Methane
e. Nitrous oxide
f. Helium

3. Atmospheric greenhouse gases make the earth’s average temperature:
a. Warmer
b. Cooler
c. Do not affect Earth’s temperature

4. To stabilize carbon dioxide concentrations (keep them from growing) in the atmosphere, carbon dioxide emissions from human activities must:
a. Be kept at current levels
b. Be increased
c. Be reduced
d. Be measured

5. When coal or oil is burned for electricity, it makes:
a. Radiation
b. Ozone
c. Carbon dioxide
d. Methane

6. The leading cause of global climate change is the presence of a hole in the ozone layer.
a. True
b. False

7. Which of the following threats will likely result from climate change? Circle all that apply.
a. Sea level rise will affect coastal communities
b. More frequent and intense storms  
c. More frequent and intense droughts  
d. Air temperature and ocean temperature will rise  
e. Increased number of heat-wave (extreme high temperature) days  
f. Increased frequency of wildfires  

8. Which of the following choices represents a way to **mitigate** (to lessen, to diminish) carbon dioxide emissions? Circle all that apply.  
a. Drive more cars  
b. Use solar electricity  
c. Restore (plant) coastal vegetation  
d. Burn more coal  
e. Ride your bike or walk to nearby places  

9. Which of the following is a way to **adapt** (adjust) to climate change? Circle all that apply.  
a. Reduce use of fossil fuels  
b. Preserve the habitat of plant and animal species that are especially vulnerable to climate change  
c. Teach about climate change in schools  
d. Plant different crops that can better stand a changing climate  
e. Move roads, railways and buildings away from low coastal areas vulnerable to sea level rise  

10. As climate change alters environmental conditions, species will have to adapt to the new conditions or move to find more suitable (better) conditions elsewhere to survive.  
a. True  
b. False  

11. Name one thing you did today (besides breathing) that produced carbon dioxide.  

12. Name one thing you or your community can do to reduce carbon dioxide emissions to the atmosphere.  

13 a. What is one thing you or your community could do to prepare for or adapt to future changes in climate.  

13 b. Explain how or why your suggestion would work.  

14. Which of these is a coastal or marine ecosystem that can be found in San Diego County. Circle all that apply.  
a. Kelp forest  
b. Rocky reef  
c. Coral reef  

e. Mangrove swamp  
f. Seagrass meadow  
g. Salt marsh
d. Sandy beach

15. Have you ever been to a Marine Protected Area?
   a. Yes
   b. No
   c. I don’t know

16. Have you ever done one of the following activities in San Diego County? Circle all that apply.
   a. Kayaked in the ocean
   b. Been on a boat in the ocean
   c. Collected scientific data on the beach or in the ocean
   d. Learned about the ocean or coastal ecosystems while on the beach or on a boat
   e. None of the above

17. In your own words, explain what a Marine Protected Area is, or what you think a Marine Protected Area is.

18. How might a Marine Protected Area help address climate change impacts?
Answers:

1. The difference between weather and climate is:
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   b. Weather includes more variables like moisture and wind, while climate just focuses on temperature
   c. Weather is predictable, but climate is not.
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10. As climate change alters environmental conditions, species will have to adapt to the new conditions or move to find more suitable (better) conditions elsewhere to survive.
   a. True
   b. False

11 - 13 b. Answers will vary

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   c. Coral reef
   d. Sandy beach
   e. Mangrove swamp
   f. Seagrass meadow
   g. Salt marsh

15 - 18 Answers will vary