CRYSTAL COVE
CONSERVANCY

VIRTUAL COASTAL DYNAMICS TEACHER GUIDE

Topic: Coastal Dynamics
Grade Level: 7-12
Unit Length: 10 sessions

Unit Overview
Student teams investigate how Crystal Cove State Park's beaches are changing and determine what we can do to protect them. As they step into the shoes of environmental engineers, students define the problem, design a model to explore how different factors affect the shape of our beach, record and analyze data, propose a solution to protect the beach, and share their recommendations with Crystal Cove State Park.

Essential Questions:
- How is the Crystal Cove State Park's beach changing over time?
- What can we do to protect it?

NGSS Performance Expectations
MS-ETS1-1
HS-ETS1-1
HS-ETS1-3
HS-ESS3-6

NGSS Crosscutting Concept
Systems & System Models

Welcome to Crystal Cove Conservancy's Coastal Dynamics educational program! As you and your students take part in real coastal engineering research at Crystal Cove State Park, you'll help researchers and natural resource managers understand how our beaches are changing over time.

The Coastal Dynamics program is the result of a unique partnership between Crystal Cove Conservancy, Crystal Cove State Park, UC Irvine researchers, and local educators. During this extended program, student project teams are introduced to how we can use environmental engineering approaches to mitigate and adapt to human-caused changes within natural beach systems. By engaging in the practices of environmental engineering, students develop a deep understanding of how environmental systems operate over time and build skills to engage in engineering problem solving, environmental research, and stakeholder communication, preparing them to become informed stakeholders in the future.

Normally, the Coastal Dynamics program involves an integrated curriculum that links classroom learning to a field trip to Crystal Cove State Park. During the 2020-2021 school year, as a result of COVID-19, we have adapted the Coastal Dynamics program so that students can participate virtually without the field experience.

If you would like more information on the program or would like to officially join, please contact Erick Valdez, Crystal Cove Conservancy Education Coordinator, by emailing *erick@crystalcove.org*.

If you have taken part in the Coastal Dynamics program, we would love to hear from you! Please *fill out this participation form* if you have used any of the modules or would like to leave feedback.

Our Park

Located on the coast in the area that is today known as Orange County, Crystal Cove State Park is located on the traditional lands and waters of the Acjachemen and Tongva tribal nations. We are deeply indebted to these tribal nations for their continuing role as the caretakers of these lands and waters, and are committed to uplifting their voices and perspectives through our work.

Crystal Cove State Park today is a green enclave within suburban Orange County. It consists of 3.2 miles of protected coastline, 2,400 acres of backcountry in Moro Canyon, and a 1,150-acre offshore underwater park, designated as the Crystal Cove State Marine Conservation Area in 2012.

The park features the federally-listed Historic District, which includes an enclave of forty-five vintage coastal cottages originally built as a seaside colony in the 1930s and 1940s and a preserved Japanese school house, which was built by the area's Japanese farming community before they were deported by the federal government to internment camps during World War Two.

Who We Are

Crystal Cove Conservancy is the nonprofit public benefit partner to Crystal Cove State Park, supporting important preservation, education, and conservation initiatives to cultivate our planet's next generation of environmental stewards ensuring that Crystal Cove, and places like it, live on for generations.

The Conservancy's unique STEM (Science, Technology, Engineering, Mathematics) education programs use community science to immerse students and the public in becoming good stewards of our environment. During our programs, students take part in real scientific investigations, working alongside researchers and land managers to investigate challenges faced by Crystal Cove State Park. Student findings inform real land management decisions, and past student data has even been included in *academic publications*, furthering our understanding of how best to protect wild places like Crystal Cove State Park.

For questions regarding the Coastal Dynamics program curriculum, logistics, and field trip scholarships, please contact:

Erick Valdez

Crystal Cove Conservancy Education Coordinator

(949) 258-3439

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Our Philosophical Approach to Engineering Education

Crystal Cove Conservancy's STEM education programs are anchored in the idea of science-as-practice: that the best way to learn science is to do science. All of our programs integrate a three-dimensional approach to learning that aligns with the Next Generation Science Standards.

Our commitment to science-as-practice means that your students will really be helping to advance scientific knowledge as they participate in our STEM education programs. The research that they take part in is real, addressing real questions from scientists and land managers. Every year, we go into our program season unsure of what they'll find. Student data has even been included in scientific journal articles, like *Dr. Peter Bryant's article* on DNA barcoding techniques for plankton that was published in PLoS.

We also ground our work in sociocultural approaches to learning. We believe that people learn best by engaging in conversation with each other. Explaining reasoning out loud, asking questions of our peers, and responding to critique allows us to develop and test our ideas about how the world works. It also mirrors how professional scientists work by engaging in discussion and challenging ideas together.

Our Approach to Equity & Access

We believe in an assets-based approach to environmental education. The environmental movement has a long history of systematically excluding Black, Indigenous, and People of Color from both the movement itself and from parks and other outdoor spaces. Through programs like the Coastal Dynamics program, we aim to empower youth so that they know that they can make a meaningful contribution to conservation.

We also recognize that all learners are natural scientists who possess an innate curiosity about the world. When students take part in the Coastal Dynamics program, they are not learning to do science from scratch, but are practicing and refining the scientific skills that they already possess.

We are deeply committed to improving accessibility to our programs. Videos are close-captioned, and we've provided family-oriented materials in Spanish and English. If you need a different language or other technology to make the program more accessible for your students, please let us know.

Introduction to the Environmental Problem

Our beaches and coastline are a quintessential part of California's collective identity. Nearly 70% of Californians live within the coastal portions of the state.[1] We spend summer days adventuring to the coast, playing in the ocean, and relaxing on the beach with our family. Public access to the coast is protected through the *California Coastal Act (1976)*, which established that private development cannot inhibit the public's right to access the ocean, coastline, and beaches.

Although they may evoke thoughts of peaceful escape, our beaches are dynamic systems that are constantly changing. At Crystal Cove State Park, gentle waves help to build up sandy beaches during the summer, which are then pounded and eroded by winter swells. Sand circulates through a mostly self-contained littoral cell, moving between the shore and offshore underwater deposits. The sediment in this system is replenished as it is washed down rivers and erodes from sandy cliffs.

However, the impacts of human use are altering these natural systems. Climate change has caused more frequent and more powerful storms, which create larger waves and can cause flooding or increased erosion. The hardening of waterways and cliffs has caused a reduction in sand replenishment. Sea level rise, although not so impactful now, will cause tides to grow increasingly higher in the future. All of these challenges put Southern California's iconic sandy beaches and valuable beachfront property at risk.

In addition, there are challenges involving equity and access. Systemic barriers have denied Black, Indigenous, and People of Color access to California's iconic beaches. At Crystal Cove State Park, this is particularly true of our Indigenous tribal nations, the Acjachemen and the Tongva, who cannot afford to live in the area and have been denied easy access to the park's protected space. If we decide to protect property over preserving access for excluded groups or reducing impact on ecological function, then we are making an intentional trade-off.

[1] *NOAA Office for Coastal Management*, 2021.

Studying Crystal Cove's North Beach

Crystal Cove State Park's Historic District offers a microcosm to study these issues up close. The Historic District, which was built in the 1920s and 1930s, is one of the last remaining examples of what early American coastal communities looked like in California. It consists of forty-five beachfront cottages and a Japanese language schoolhouse, built by the area's Japanese American farming community in the 1930s. Twenty-eight of the cottages and the schoolhouse have been restored. Most of these have now been converted into low-cost overnight rentals, allowing families to spend the night at the beach.

Restoration is currently underway on the remaining seventeen cottages, which will hopefully be complete by 2025. These seventeen cottages are all located along an area known as the North Beach. This particular section of the Historic District was saved for last because it is geographically challenging, located very close to the water with crumbling cliffs behind them, and without a road for easy construction access. The beach near these North Beach cottages is susceptible to flooding and high tides, making it an ideal place to think about the challenges created by coastal change.

The Challenge for Students

During the Coastal Dynamics program, your students will have the chance to explore the real-world challenges created by our changing environment by investigating how Crystal Cove's North Beach is changing. Participating students will use the environmental engineering process as a scaffold as they define the problem that they will help solve, build a model of the environmental system, collect and analyze environmental data to see how the beach is changing, explore possible solutions, and then share their recommendation with stakeholders.

The work that student project teams do together during the Coastal Dynamics program will have real impacts. No one knows the best strategies to use in order to address changing beaches in California, especially when it comes to balancing the interest of different stakeholder groups, many of whom have been historically excluded from this process. Their analysis will help us to better understand how Crystal Cove State Park's North Beach is changing over time, and their approaches will also help us begin to consider creative solutions to balance different stakeholder interests and protect this important place in the future.

Driving Questions
How is the Historic District's North Beach changing over time?
How can we apple creative ideas and take into account competing stakeholder interests to protect places like Crystal Cove's North Beach in the future?

Learning Outcomes

During the Coastal Dynamics program, students will be immersed in the practices and processes of scientific research as they investigate how Crystal Cove's beaches are changing. By participating in the full program, they will build a broad understanding of coastal dynamics, coastal and environmental engineering approaches, and how engineers and natural resource managers can use ideas about environmental systems to protect places like Crystal Cove State Park's beaches.

By the end of the program, your students will be able to…	You can assess this using…
1. *Participate* productively in scientific practices and the discourse of science.	Observations of student discussions throughout the program
2. *Explain* how beaches are dynamic, constantly changing systems, and describe standard practices that communities use to mitigate and address this change.	Field notebook reflections throughout the program
3. *Concisely define* and summarize a problem related to Crystal Cove's North Beach that can be solved using environmental engineering strategies.	Problem statement in Session 1
4. *Construct* a visual model of a beach system that shows how different environmental and anthropogenic factors affect the volume of sand on the beach.	Project team models, created in Session 2 and revised in Session 4
5. *Validate* their initial ideas by collecting data on the real-world system and using it to test the assumptions in their model.	Project team models, updated in Session 5
6. *Use* ideas about computing and statistics to create mathematical representations showing relationships between different factors in their model.	Project team products in Session 6-7
7. *Construct* evidence-based explanations about how Crystal Cove's North Beach is likely to change over time, both now and in the future.	Project team products in Session 8
8. *Recommend* a solution that reduces the future impact of beach change on Crystal Cove's North Beach and meets defined criteria and constraints.	Project team recommendations in Session 9
9. *Apply* science communication strategies to design a presentation that justifies their recommended solution.	Project team presentation in Session 10
10. *Reflect* on how we can use environmental engineering strategies to protect places like Crystal Cove State Park's North Beach.	Project team presentation and field notebook reflections in Session 10.

Next Generation Science Standards Alignment

The Coastal Dynamics program is aligned with the three-dimensional approach of the Next Generation Science Standards. As students engage in community science research that focuses on a specific disciplinary core idea, they utilize engineering practices to identify and develop solutions to a real-world problem. Our programs frame engineering investigation through the crosscutting concept lens of Systems & Systems Models, challenging students to think about the visible and invisible interactions that affect environmental systems at Crystal Cove State Park.

By taking part in the ten sessions, students will be able to demonstrate understanding in the following areas:

Performance Expectations

Middle School

- **MS-ETS1-1.** Engineering Design. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- **MS-ESS3-2.** Earth's Systems. Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.
- **MS-PS3-5.** Energy. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

High School

- **HS-ETS1-1.** Engineering Design. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
- **HS-ETS1-3.** Engineering Design. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.
- **HS-PS4-1.** Waves and Their Applications in Technologies. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.
- **HS-ESS2-2.** Earth's Systems. Analyze geoscience data to make the claim that one change to Earth's surface can create feedback that causes changes to other Earth systems.
- **HS-ESS3-1.** Earth and Human Activity. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.
- **HS-ESS3-6.** Earth and Human Activity. Use a computational representation to illustrate the relationship among Earth systems and how those relationships are being modified due to human activity.

Science Practices

1. Defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and developing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Crosscutting Concept

- Systems and System Models
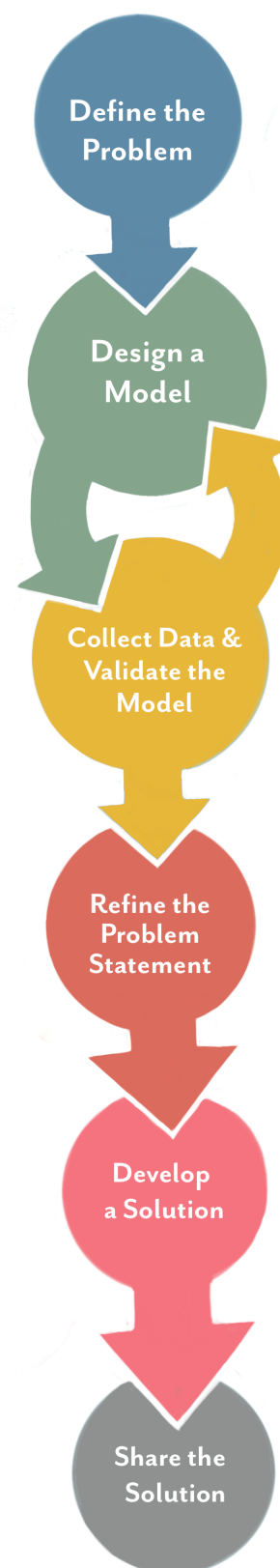
The Environmental Engineering Process

As students take part in the Coastal Dynamics program, they'll be stepping into the shoes of coastal engineers as they define the problem, investigate the environmental system, and explore possible solutions.

The engineering process that we use as a frame for this program is different from the typical design-build-test process common to engineering education. As the Crystal Cove Conservancy team began collaborating with coastal and environmental engineers to develop the Coastal Dynamics program, the engineers highlighted the fact that the typical design process is only common in certain fields within engineering. When dealing with a large environmental problem, the solutions are so costly and so permanent that there isn't a way to build and test a design.

To address this, we collaborated with the engineers to propose a new approach to test within our coastal engineering educational program. This process, though different from the engineering design cycle that many students will be used to, better matches the way that environmental engineers approach problem-solving.

This environmental engineering process is introduced to students in Session 1, and acts as a framing lens for all of the program sessions. The major steps include:

- *Define the Problem:* Initially in Session 1, students are tasked with exploring the real-world challenge and developing a concise problem statement that explains what the problem is, what it impacts, and why it is important to solve.

- *Design a System Model:* In an iterative process starting in Session 2, students develop a systems model showing their initial ideas about computational relationships within the environmental system. They then investigate the science involved in the system (Session 3) and use what they've learned to refine their model (Session 4).

- *Collect Data & Validate the Model:* After developing and refining a model, students collect data on how the real-world environment is changing (Session 5) and then analyze their data and use it to check and see if the assumptions in their model match the real-world relationships (Session 6-7).

- *Refine the Problem Statement:* Once students have explored how the environment is currently changing and made predictions about how it will change in the future, they revisit and refine their original problem statement (Session 8).

- *Develop a Solution:* Students work in problem teams to identify and justify a solution (Session 9).

- *Share the Solution:* Students develop a presentation to share their solution with Crystal Cove Conservancy, Crystal Cove State Park, and other stakeholders (Session 10).

Define the Problem

Design a Model

Collect Data & Validate the Model

Refine the Problem Statement

Develop a Solution

Share the Solution

Session Overview

Session	Overview	Length
1 *Designing the Problem*	Students are introduced to the Coastal Dynamics program, divide into project teams, and start their field notebooks. After, they visit Crystal Cove State Park's Historic District virtually and create a problem statement that describes the problem they are tasked with solving.	**45-60 minutes**
2 *Designing a Model*	Project teams reflect on how we can define the system we want to study, and then design a model that shows their initial ideas about how environmental and anthropogenic factors affect the amount of sand on the beach.	**Two sessions of 45-60 minutes**
3 *Diving Deeper (Optional)*	In this optional session, project teams revisit their questions about their model and participate in short background investigations to build their understanding of changing coastal systems. This session is flexible, with multiple investigations that teachers can choose to implement.	**Two sessions or more of 45-60 minutes**
4 *Refining Our Model (Optional)*	In this optional session, project teams share what they've learned, revise their model to incorporate new ideas, and identify what they might measure or monitor to test the assumptions in their model.	**45-60 minutes**
5 *Collecting Data*	Project teams visit Crystal Cove State Park virtually and help collect data on different factors from their model.	**45-60 minutes**
6 *Coding a 3D Representation (Optional)*	In this optional session, project teams are introduced to Octave, a free data analysis program. They learn to manipulate code in order to create three-dimensional models of Crystal Cove's North Beach.	**45-60 minutes**
7 *Analyzing Data & Validating Our Model*	Project teams graph and analyze data, and then use their findings to test the assumptions in their model of the beach system.	**45-60 minutes**
8 *Refining Our Problem Statement*	Project teams revisit their problem statement from Session 1 and refine it further. They also identify criteria and constraints for their solution and come up with metrics to evaluate proposed solutions.	**45-60 minutes**
9 *Developing a Solution*	Project teams work together to identify and explore a possible solution to protect Crystal Cove's changing beach.	**At least one session of 45-60 minutes**
10 *Sharing Our Solution*	Project teams develop a presentation to share their findings with Crystal Cove State Park and other stakeholders.	**At least one session of 45-60 minutes**

Required Student Assessment

Crystal Cove Conservancy has pre- and post-assessments to help us evaluate the program's effectiveness, measure its impact on students, and report back on student learning outcome to our funders.

Before you start the Coastal Dynamics program, please ask students to complete the pre-program assessment. After completing your last session of the program, please have them fill out the post-program assessment. You can assure students that their responses to these two assessments will not be graded or scored -- they're simply to help us assess the program itself.

Student Pre-Program Assessment: http://bit.ly/2NZvJo3
Student Post-Program Assessment: http://bit.ly/2PobWPq

Basic Session Structure

Each session within the Coastal Dynamics program is broken down into four sections. These sections align with the five elements of the BSCS 5E Instructional Model (although we use slightly different names).

Launch
(or Engage)

At the start of every session, a short video introduces students to the day's driving question and invites them to share their initial ideas.

Explore

Next, students take part in short investigations related to the module's driving question. These investigations are designed to be flexible, and can take place during scheduled class time or independently outside of class.

Share
(or Explain & Expand)

Students come back together to share their observations and discuss their ideas with their peers. These discussions may take place in student research teams or as a whole class. In the Session 1 slideshow, we've included slides with suggested science discussion norms, sentence starters, and suggested questions to get you started! You can adapt these for your class.

Reflect
(or Evaluate)

At the end of each session, students watch a video prompt and reflect on what they've learned so far in their field notebook.

Technological Platforms

Throughout the Coastal Dynamics program, we use a few different technological platforms to support student learning.

Sharing Information

Most of the program's presentations are hosted on *Google Slides*, with videos embedded from our *Crystal Cove Conservancy Education Youtube* account. Due to school permissions, you will likely need to make a copy of each Google Slides presentation on your school Google account so that students can access it.

Exploring Places Virtually

Thinglink is an easy-to-use platform that allows organizations to create interactive photo maps that users can click on and explore -- including 360-degree photos. During the Coastal Dynamics program, students will use Thinglink *to take a virtual tour* of the Crystal Cove Historic District in as they explore the problem that they're going to help solve. Later, they visit another Thinglink in Session 5 to help collect environmental data. (You will not need to know how to set up Thinglink, other than demonstrating how to access the virtual explorations and click through it!)

Creating Models

You can choose between two different options for students to use when they create a model in Session 2. The Session 2 lesson guide has more specific information on the advantages and disadvantages of the two platforms.

- *Padlet* is a collaboration platform similar to an online bulletin board, which will let multiple students collaborate and build a model at the same time. Free accounts (which students can sign up for) can create up to three Padlet boards. Pro accounts, which let a user create unlimited boards, start at $8/month. If you don't have access to Padlet but prefer a collaborative option for modeling, you might consider using *Google Jamboard* or another *online collaborative whiteboard* instead.

- *SageModeler* is a free, online modeling tool that can be used to build computer simulations of systems. Although it is challenging to collaborate on SageModeler because only one person can manipulate the model, this platform will also allow students to easily define computational relationships between different factors in their models and simulate how environmental change will affect them.

Building a Three-Dimensional Model

In the optional Session 6, students use an open-source program called *GNU Octave* to manipulate code and create a three-dimensional model of Crystal Cove's North Beach. This does not require extensive knowledge of coding. In Session 6, we provide resources and instructional videos to introduce students to each task and to help them troubleshoot.

Analyzing Data

You can choose between two different options for students to use when they analyze data in Session 7. Again, the Session 7 lesson guide has more specific information on the advantages and disadvantages of the two types of platforms.

SageModeler has the ability to create graphs and display data using visualizations that are deliberately designed to help students think about data distribution and outliers. This can help students to build a conceptual understanding of ideas like statistical significance. It is also easy to use, which makes it ideal for younger students. However, it is challenging to collaborate on SageModeler because only one person at a time can manipulate it, and it is not a platform that would be used by practicing researchers.

Google Sheets is a more traditional data analysis platform that is very similar to Microsoft Excel. It allows students greater freedom in creating graphs and performing calculations, and it can also be accessed collaboratively, with multiple students working on the same document in real time. However, using Google Sheets requires students to be more attentive to the step-by-step process involved in creating graphs and performing calculations, which can detract from conceptual understanding.

If you prefer another platform that serves a similar purpose, please feel free to substitute it in. If you or your students have any trouble accessing the slideshows or videos, please contact Erick at *erick@crystalcove.org*!

Decisions to Make

Before beginning the Coastal Dynamics program, it will be helpful to think through how you want to integrate and support a few key aspects of the program. Below, you'll find more information on four key decisions that you may want to make.

Supporting Collaboration

We often learn science best by engaging in discussions and collaboration, but COVID-19 restrictions and time limitations make it challenging to support collaboration. As a result, it's worth thinking ahead about ways that you can intentionally support student collaboration.

We recommend dividing students into project teams early in Session 1. Students will continue to work in these same teams throughout the program. If you are teaching in a fully online or hybrid environment, you might consider dividing into small discussion groups on Zoom or giving students options to meet in their project teams independently.

Integrating Field Notebooks

Throughout the Coastal Dynamics program, students are encouraged to use field notebooks to take notes, record observations, plan investigations, and reflect on their own thinking. This is intended as a teaching tool to support metacognition. Before beginning the program, we recommend thinking through the logistics of the field notebooks.

- *What kind of journal do you want students to use?* If you want to give students an opportunity to get off of their computers, you may ask them to use a physical field notebook, like a notebook, notepad, or paper stapled together. Individual Google Docs work for a digital option, which may be easier to review and assess.

- *How much scaffolding do you want to give students?* There is benefit to letting students use a free-form notebook, since it will force them to think through how to structure their thinking. However, some students may need more support which can come from pre-designed pages. If you would like to provide students with more scaffolding, we have provided scaffolded field notebook pages for each lesson.

- *How will you assess the field notebooks?* Consider whether you want to collect the journals, or if it's better to ask students to share photos of their entries so that you can assess their learning.

Assessing Student Work

Assessment can be challenging during COVID restrictions, so it is worth thinking ahead about how you will monitor and assess student learning. In the module lesson guides, we've identified learning outcomes for each module, along with suggestions for assessments.

- *For formative assessments,* you can observe student science journals and other student-created work, monitor students during discussions, and have students share a personal reflection at the end of each module.

- *For summative assessments,* you might decide to use our pre- and post-program learning assessments or have students or grade research team's final product using a rubric.