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Bringing critical systems thinking to high school students through ocean acidification research

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Our 4th module – Ocean Acidification: A Systems Approach to a Global Problem

- Model current interdisciplinary research and connect to the work of others.
- Teach the process of thinking.
- Students as scientists and delegates.
- 3-5 weeks of class time.

Photos: [genome.jgi-psf.org/Thaps3](http://genome.jgi-psf.org/Thaps3), [www.pnas.org/content/105/5/1391/F1.expansion.html](http://www.pnas.org/content/105/5/1391/F1.expansion.html)
Main Goal

Analyze the effect CO$_2$ has on ocean chemistry, ecosystems and human societies

Classroom exercise: analyzing a social network

1. In an interactive group activity, students use familiar cell phone networks to learn about how information can be easily depicted.

2. Students pull together the class information to quickly learn that even when working in a team of five, it is still difficult to organize and analyze all of the information.
Motivation to use tools to solve problems
Systems thinking enables behavioral changes

<table>
<thead>
<tr>
<th>Habits of a Systems Thinker</th>
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<tbody>
<tr>
<td>Seeks to understand the big picture</td>
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<tr>
<td>Observes how elements within systems change over time, generating patterns and trends</td>
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<tr>
<td>Recognizes that a system’s structure generates its behavior</td>
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<tr>
<td>Identifies the circular nature of complex cause and effect relationships</td>
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<tr>
<td>Surfaces and tests assumptions</td>
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<tr>
<td>Considers how mental models affect current reality and the future</td>
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<tr>
<td>Considers both short and long-term consequences of actions</td>
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<tr>
<td>Finds where unintended consequences emerge</td>
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<tr>
<td>Recognizes the impact of time delays when exploring cause and effect relationships</td>
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<tr>
<td>Checks results and changes actions if needed: “successive approximation”</td>
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<tr>
<td>Changes perspectives to increase understanding</td>
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<tr>
<td>Considers an issue fully and resists the urge to come to a quick conclusion</td>
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Poster: Waters Foundation

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Lesson 1 (Introduction through case studies): Understand the broad reach and accessibility of ocean studies and gain the critical thinking skills to properly evaluate news media.
Lesson 2: Exploring CO₂ in the lab

A. Use inquiry to understand CO₂.
B. Learn the basics of the changing carbon cycle and ocean acidification.
Lesson 3

• Watch Acid Test video – realize this is a global problem with many stakeholders
• Setting the stage to model a collaborative lab group
• Is this a situation that requires a systems study?
  – Many parts with interactions, emergent properties, reverberating effects?
Does this require a systems study?

- ?
- Phytoplankton (photosynthesis)
- Marine Organisms (respiration)
- Trees and Plants (photosynthesis)
- Animals (respiration)
- Combustion Reactions
Lesson 4-5: Exploration of the effects of changing nutrient and carbon cycles

• In interest groups, experiment, analyze public (online) data, and prepare for a mock summit to address concerns.

• Main question: What effect does the increasing atmospheric CO₂ have on the ocean and its subsystems?
  – Model collaborative research by completing a cohesive set of experiments in order to determine the correct interactions within their sub-networks
  – Emphasis on need for multiple and diverse data
  – Need for multiple stressors
Options

A. Student interest groups each design their own experiment

B. ~ 8 protocols available for student groups to complete – slight variations
   • Diatoms – various nutrient, CO₂ entry, water, temperature, salinity types
   • Shell and bone dissolution with sea urchin online lab
   • Physical chemistry experiments
Growth curves as determined from hemocytometer counts performed by ISB high school interns
Need for multiple & diverse data

- Daily culture measurements:
  - Cell count using a hemocytometer
  - OD 600 reading/Fluorometer reading (depending on what technology is available)
  - Pigment description
  - Pigment extraction experiment
    - Chromatography

Example of experiment design

5g of dry ice were used to stabilize CO₂ levels at approximately 2000 ppm. pH of seawater dropped from 8.0 to 6.5 overnight. Shells left in seawater lost 2% of their mass over 3 days.
Supplement their experiment with online data component.

- Bad Acid: Sea Urchin Simulation
- C-MORE
- WA State Department of Ecology (Eyes over Puget Sound)
- Multiple in situ sensors
- Ice Core studies
- Mesocosm studies
- Many NOAA resources
- Carbon footprint calculators
NetLogo / Java simulation for generating hypotheses.
Lesson 6: Mock Summit

Students as scientists and delegates
Discuss findings and next steps for all parts of the system

• Emphasis placed on the impact on the subsystem and system.

• Students reflect on unanswered questions, next steps and on what their roles
  – How they might change their actions in order to impact the network?
  – What does their final, class experimental network look like?
Atmospheric CO2 Level

CO2 Absorbed by Ocean

CO2 Polluting Nations

Developing Island Nation Economies

Oxygen

CO2 Absorbed by Ocean

渔场

碳酸

钙碳酸

海生钙化有机体

Diatoms

碳酸酸

钙碳酸

海洋营养

营养物质

较高营养级

依赖于海洋钙化者的鱼类
Is it working?
• Yes! They’re learning, engaged, and thinking - systemically and locally.

Where are we going next?
• Genetic component, with predictions of future responses, acclimation and adaptation

Thank you for listening – please visit me for more information.

http://staff.wwu.edu/stefan/salish_sea.shtml
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- Our curriculum team...
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