DEVELOPING SECONDARY TEACHERS' UNDERSTANDING OF SCIENTIFIC AND ENGINEERING PRACTICES FROM THE NEXT GENERATIONS SCIENCE STANDARDS IN THE CONTEXT OF CLIMATE CHANGE

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2013 Teacher Quality Partnership Grant Program, Office of Higher Education, and the National Science Foundation (InTeGrate, PBL Projects)

Project

Mitigating Impacts of Climate Change: Interdisciplinary STEM and CCSS Pathways

Funded by the 2013 Teacher Quality Partnership Grant

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Project Goal

- Improve the instructional preparation of STEM secondary teachers through intensive and focused professional development (PD) by integrating rigorous STEM content with scientific and engineering practices (Next Generation Science Standards NGSS)).

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Project Outcomes

1. Know how to incorporate scientific and engineering practices as part of their instructional practices.
2. Understand the interactions between the earth systems (e.g. climate change) and the human systems (e.g. creating alternative energy sources).
3. Collaborate to implement interdisciplinary STEM content that emphasizes inquiry- and problem-based learning.

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Participants

- This eight-day summer professional development (PD) institute included 20 STEM middle and high school teachers from four districts.
  - Interdisciplinary school-based teams were recruited from each district (e.g. one science, math, and tech ed.).

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Project Summary

Summer Session: Jun 25-Jul 3 (8 sessions)

- **Major Activities**
  - **Climate Change-After the Strom (SCI)**
  - **Flo Design (ENG)**
  - **Planning Teaching Modules (e.g. Unit)**

Summer follow-up sessions: July-Oct

- **STEM Module Development**
  - SCI & ENG practices
  - CCSS (Literacy/Math)
  - PBL/5E Learning Cycle

Academic year follow-up sessions : Oct - June

- **Action Research**
  - Implements Module
  - Examines a factor of student acheivment from the teaching module

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Linking Science and Engineering

- The summer professional development (PD), teachers completed two authentic inquiry- and problem-based activities.

After the Storm (science)

Climate Change

Interdisciplinary (e.g. human-earth systems)

Authentic Data

Systems Thinking

NSF-InTeGrate

Flo Design (engineering)

Mitigating the Effects of Climate Change

Problem Analysis

Independent Research

Brainstorming

Testing Ideas

NSF-PBL Projects

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Linking the climate change activities with the SCI and ENG Practices

PRACTICES FOR K-12 SCIENCE CLASSROOMS
1. Asking questions (for science) and defining problems (for engineering)
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 (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Although all practices were used, the framework of the activity focused on this practice

After the Storm

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Climate Change—After the Storm

- Teachers investigated the following socio-scientific issue:
  - To what extent should we build and/or rebuild coastal communities?
- To refine the above issue, the following scientific research question was posed:
  - To what extent are coastal communities at risk due to climate change?

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After the Storm—Part 1

Learning Goal—Situate context and engage teachers' prior knowledge

- **Column 1**—a 6-minute NBC video, *Rising Sea Levels*
- **Column 2**—NY Times article, *After Sandy: Why We Can't Keep Rebuilding on the Water's Edge*
- **Column 3**—Several data charts from the *IPCC Summary Report* (e.g. Components of Climate Change Processes

After The Storm—Summary Charts

Part 1: The Issue (OWL Chart)

	Effects of Climate Change	Effects of Extreme Weather on Coastal Communities:	Human and Natural Drivers of Climate Change
This is what I **OBSERVED**			
This is what I **WONDER** about			
This is what I **LEARNED**			

Muddiest Point:

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After the Storm—Part 2

Step 3: Research Geoscience Data (60 minutes)

Conduct this research as a jigsaw activity. First, have each student in their "study area" group select a data set:

Data Set 1: Global temperature
Data Set 2: Sea level
Data Set 3: Greenland ice sheet
Data Set 4: Intensity of tropical cyclones

NOTE: It is recommented to have one student complete Data Sets 1 and 2 - this should be one expert group. This is because the other two data sets are more time consuming to complete.

Then, divide students into their "expert" groups to collect, organize, and analyze the geoscience data. Depending on the size of the class, students can be assigned to multiple student "expert" groups, meaning there can be three ice sheet "expert" groups in one class. Each "expert" group should use the guided prompts and questions, which are located in the student handout. Make sure to tell students to record their findings on a seperatre sheet of paper because they will share what they learned with their "study area" group.

IMPORTANT: *It is highly recommended that the instructor review and "play around" with the data and programs ahead of time, even if you are familiar with the data. Students are most likely going to have many questions, not just about data interpretation, but also how to use Google Earth. Be prepared to respond to student inquires. Additional resources are located at the bottom of the page to help you better understand Google Earth, KML files and MS Excel.*

Learning Goal—Engage teachers in the scientific practices (e.g. geoscientific thinking)

Part 2: Issue Investigation (Use the electronic version on Schoology to record your team's responses)

Socio-scientific Issue (SSI): To what extent should we build and/or rebuild coastal communities?				
Scientific Research Question (SRQ): To what extent are coastal communities at risk due to climate change?				
Context (Study Location):				
Data Set	Data Analysis	Working Hypotheses—Response to SRQ	What the Literature Says (evidence)	Revised Working Hypotheses—Response to SSI
Data Set 1: *Temperature*			Climate Change Literature	
Data Set 2: Sea-level				
Data Set 3: Ice Sheets			Cost of Rebuilding Literature	
Data Set 4: *Intensity of Tropical Cyclones*				
Data Set 5: *Future Projections (3 sets)*				

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The summary slide below is one group's summary of the climate data

Summary of Evidence from the Climate Change Activity

- Trend in GHG ↑
- Temperature ↑
- Sea Level ↑
- Ice coverage of the Greenland Ice Sheet ↓
- Intensity of Tropical Cyclones ↑ ?
- Future CO2 Emissions ↑ ?
- Future Temperature Predictions ↑ ?

Should we build coastal communities?
insurance, taxes, build storm surge barriers, build natural barriers, move residents and businesses

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After the Storm—Part 2

Table 2: Issue Investigation

Socio-scientific Issue (SSI): To what extent should we build and/or rebuild coastal communities?				
Scientific Research Question (SRQ): To what extent are coastal communities at risk due to climate change?				
Context (Study Location): Shoreline of Cape Cod, Massachusetts (Ocean and Bay area) 181.4 miles Population: 215,888 Demographic: <90% White Urbanization: Quadrupled in the last 40 years Concentrated in Barnstable and Falmouth. Decreases towards Northeast (Provincetown and Truro) Elevation: Below 100 feet				
Data Set	**Data Analysis**	**Working Hypotheses—Response to SRQ**	**What the Literature Says (evidence)**	**Revised Working Hypotheses—Response to SSI**
Data Set 1: *Temperature*	The rate of temperature range between Aswan, Alice Springs, Moscow, Akuryri, and Allentown were all within less than 8 degrees Celsius. All of the Highest temperatures were recorded after 1979 while the lowest recorded temperatures happened before 1979.	If carbon dioxide emissions continue to rise at the same rate then coastal communities of Cape Cod will be at significant risk because temperature and sea levels will continue to rise.	<u>Climate Change Literature</u> <u>Policy Makers</u> Anthropogenic warming influences/trends can be traced back to 1750. The evidence (air and water temp, melting snow and ice, sea level rise) all points to a warmer climate and impacts on natural systems. GHG emissions have increased 70% from 1970 to 2004. Temperature increase for Cape Cod from 1970 to 2004 is in the 0.2 to 1.0 degree Celsius range. Increases in temps are "very likely" due to human activities increasing GHG concentrations and are "likely" due to anthropogenic warming since 1950. "Human influences have: very likely contributed to sea level rise during the latter half of the 20th century; likely contributed to changes in wind patterns, affecting extra-tropical storm tracks and temperature patterns; likely increased temperatures of extreme hot nights, cold nights and cold days; more likely than not increased risk of heat waves, area affected by drought since the 1970s and frequency of heavy precipitation events."	If temperature and sea levels continue to rise then communities should not rebuild or continue to build on the coast of Cape Cod because of the socioeconomic risks.
Data Set 2: Sea-level	Lowest recorded sea levels for the New England region around Mass were documented prior to 1977 while on the other hand all the highest recorded sea level were from 2011 to present. After reading the directions it was impressive to find that Louisiana is facing sea level rises of 9.88 mm/year vs. New England's 3 mm/yr status.			
Data Set 3: Ice Sheets	Our estimation of ice melt in 1980 was 235,200 sq. mi.it increased to 309,320 sq. mi. in 1985, and increase of 76% melt as a baseline. By 1990, the increase was 77%, 1995 had a 10% DECREASE in ice melt, and has changed in 2000 and 2005 by approx. 10%.			
Data Set 4: *Intensity of Tropical Cyclones*	The relationship between the sea surface temperature and wind power according to the data collected from the MDR is when the temperature increases the wind power intensifies. In turn this had caused the tropical cyclones that have developed in the MDR in the last 20 years to be stronger.			

After teachers collected their data (e.g. decrease in terrestrial ice sheets, rising sea levels) and recorded a summary of this evidence in Table 2.

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After the Storm—Part 2

Identifying linkages between climate change (earth system) with coastal communities (human systems)

- Then teachers created a concept map that depicts their understanding of how the changing climate system might affect their study area, in this case, Cape Cod.

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Table 3: Constructing Your Argument

Introduction *(Significance of issue, Context)* Shoreline of Cape Cod, Massachusetts (Ocean and Bay area) 181.4 miles Population: 215,888 Demographic: <90% White Urbanization: Quadrupled in the last 40 years Concentrated in Barnstable and Falmouth. Decreases towards Northeast (Provincetown and Truro) Elevation: Below 100 feet		
Claim *(response to the socio-scientific question)* If temperature and sea levels continue to rise then communities should not rebuild or continue to build on the coast of Cape Cod because of the socioeconomic risks.		
Evidence Claim #1 (Description of Working Hypotheses) Temperature increasing	**Evidence Claim #2** (Description of Working Hypotheses) Sea Level increasing	**Evidence Claim #3** (Description of Working Hypotheses) Socio-economic costs
Elaborate *(Rationale of Working Hypotheses)* **Temperature increase for Cape Cod from 1970 to 2004 is in the 0.2 to 1.0 degree Celsius range. Increases in temps are "very likely" due to human activities increasing GHG concentrations and are "likely" due to anthropogenic warming since 1950.** **Current policies and mitigation practices still allow GHG increases and the projected surface temperature increases in the Cape Cod area for 2090-2099 are 2.5 to 3.0 degree Celsius increases. However, the impacts of climate change will be felt for centuries even if practices change.** **In 2030, all 3 scenarios show an increase of approximately 0.5 degrees.** **The best case (B1) in 2050 shows a rise of 0.6 degrees.** **The middle case (A1B) in 2050 shows a rise of 2 degrees.** **The worst case (A2) in 2050 also shows a rise of 2 degrees.** **In 2100, (B1 - best) shows an overall increase of 0.5 degrees, the same levels as 2030.** **In 2100 (A1B - mitigation) shows an overall increase of 3 deg.** **In 2100 (A2 - worst) shows a 4 degree overall increase.**	**Elaborate** *(Rationale of Working Hypotheses)* **Lowest recorded sea levels for the New England region around Mass were documented prior to 1977 while on the other hand all the highest recorded sea level were from 2011 to present. After reading the directions it was impressive to find that Louisiana is facing sea level rises of 9.88 mm/year vs. New England's 3 mm/yr status.** **The results of a 1 meter sea level rise will have a significant impact on P-town. Many spill ways were rivers deposit out to the sea will experience excessive bulging. If scientist's predictions are correct and by 2100 the sea levels will rise 2 meters then; P-town will become an island, Buzzard Bay will have significant flooding, and Chatham will have significant beach front property.**	**Elaborate** *(Rationale of Working Hypotheses)* **Every $1 spent on prevention can prevent $9 of damage costs. If you had a choice of 1:9 odds, what would you bet on?** **Accuweather attributes the increasing costs of coastal damages (predicted to be in the 10's of billions per year by 2100) to population increases of 17% on the Atlantic coast from 1990-2008. Half of our economic productivity is from the coastline. With most of our eastern coastline at 10 feet below sea level, we are at great risk from hurricanes and storm surges, as storm intensity is predicted to increase despite the decrease of storm frequency.** **Threats to coastal communities, according to NOAA, are extreme natural events and long term effects such as coastal erosion and sea level rise. Coastal communities should develop hazard resilience. As sea level increases and dunes are eroded, there is a threat to the wetland along the shore. Marshes serve as breeding grounds for marine life, and the loss of coastline would flood these wetlands that are necessary to the marine life cycle. Both commercial and recreational fishers depend on the marshes for their livelihood and is another factor in the cost to coastal communities.** **If it was not for humans, natural disasters would not exist.**
Counterclaim *(what is the significance of the counter claim?)* We think to rebuild before we think about the long term considerations. Short term economic instead of long term. There would be no natural disasters if it were not for humans. Without humans there are only natural events.		
Conclusion *(e.g. restate claim)* Vulnerability. Rebuilding in the same location allows for the same consequences in the future.		

After the Storm—Part 3

Learning Goal—Engage in Argument from Evidence

Socio-scientific Issue

To what extent should we build and/or rebuild coastal communities?

Scientific Research Question

To what extent are coastal communities at risk due to climate change?

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After the Storm—Results from a Pre- and Post-test

There were two content tests, a 16-question climate change content test and a 16-question flo-design test.

	Climate Change pre-test (%)	Climate Change post-test (%)	Change from pre- to post-test
(N)	19	19	0
Average	52	72	+20
Standard Deviation	13.0	9.2	-3.8
Median	57	73	+16
Mode	47	73	+26
Highest Grade	73	87	+15
Lowest Grade	20	53	+33

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Flo Design

Mitigating the Effects of Climate Change—Flo Design

- ***The Challenge:*** A team of engineers (e.g. the teachers) were tasked with developing a strategy for extracting energy from a new compact wind turbine design. This is one solution to mitigate the effects of Climate Change.

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Identifying a Real-world Context

- Before teachers investigate the issue, they review the following:
  - The Introduction
  - The Organization
  - The Problem Statement
  - Brief summary of a the discussion of the problem statement and an example of brainstorming solutions.

Introduction—Context

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Organization

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Problem Statement, Discussion, and Solution

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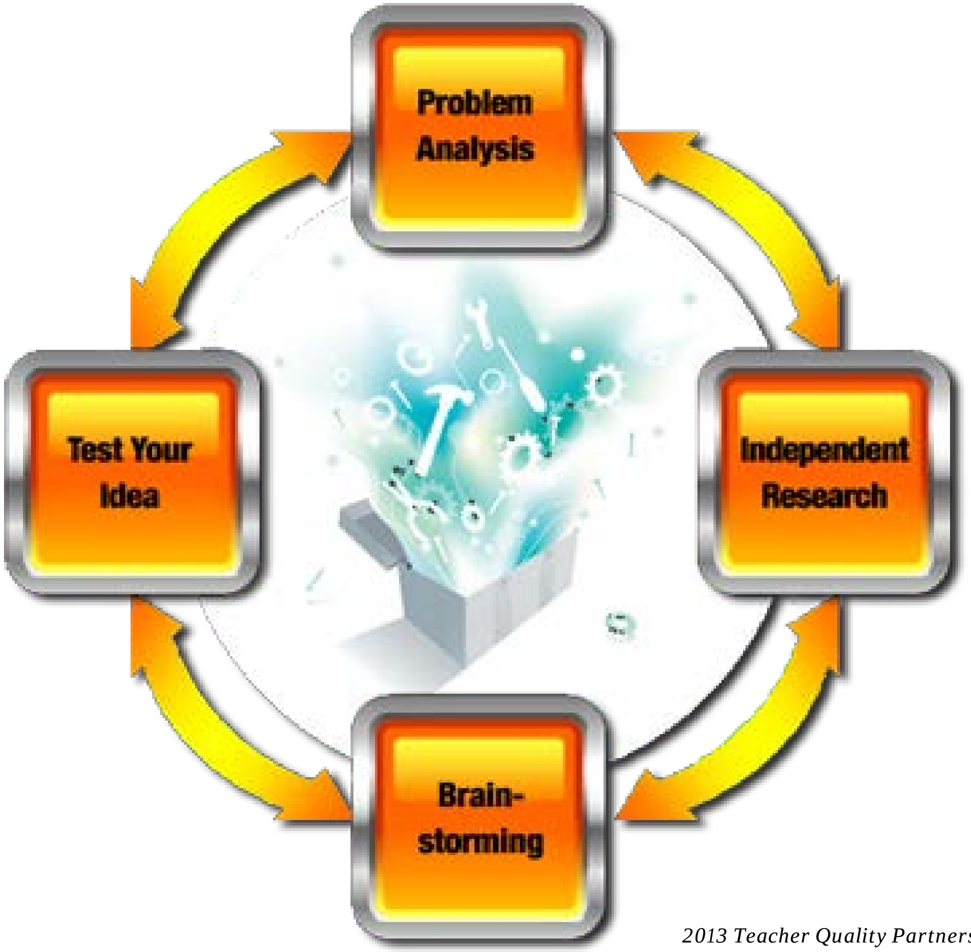
Problem-based Instructional Framework



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Flo-Design—Problem Analysis

Step I. Problem Analysis

The first step in problem solving is to clearly define the problem. Exactly what is the problem you are trying to solve and what is the desired outcome? To do this, you must first identify and list the criteria against which your solution will be measured. You must identify what you know about the problem (i.e., what is given) and any assumptions you need to make if information is missing. Once you have clearly defined the problem, you are ready to move forward and seek out the knowledge and skills needed to solve the problem.

Clearly define the problem:		
List the criteria for a successful solution.	**What do we know about the problem?**	**Are there any assumptions we must make?**

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Flo Design—Independent Research

Step II. Independent Research

Independent Research involves identifying what you need to learn to solve the problem and then developing a plan to acquire that knowledge. Given what you know about the problem from the *Problem Analysis* phase, make a list of what you need to learn. Be very specific! Then divide up the learning with your team members, set deadlines, and develop an action plan for how you and your team will acquire the knowledge and skills needed to solve the problem.

What do we need to learn? Be specific.	*Divide up the learning:* Who will do what?	How much time do we have to complete the research?	What is our action plan for acquiring the knowledge we need?

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Flo Design—Brainstorming

Step III. Brainstorming

Brainstorming involves sharing what you've learned through your independent research with your team in order to generate possible solutions This requires carefully listening to and considering the input of your teammates—it is important to exchange ideas without criticism o judgment. Through this process, you will be able to identify a solution that represents the collective knowledge of the group.

Solution ideas	Pros	Cons	Ranking

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Flo Design—Testing your Ideas

STEP IV. Testing Your Idea

Testing your idea requires developing a detailed plan to validate your solution based on the criteria you defined in the Problem Analysis phase. *A good test plan is one that someone of reasonable intelligence can follow and replicate your results.* In cases where it is unrealistic to test your solution, you should provide conclusive evidence describing how your solution addresses each of the stated criteria.

List the criteria for a successful solution identified in your *Problem Analysis.*	How does your solution address each of the criteria listed?	Describe in detail how you would test your solution.

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Flo Design—Results for Pre- & Post-Test

There were two content tests, a 16-question climate change content test and a 16-question flo-design test.

	Flo Design pre-test (%)	Flo Design post-test (%)	Change from pre- to post-test
(N)	19	19	0
Average	63	73	+10
Standard Deviation	15.0	9.5	-5.5
Median	69	72	+3
Mode	72	83	+11
Highest Grade	83	89	+7
Lowest Grade	28	56	+28

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Conclusions

- Teacher participants mean assessment score improved by 20% for the climate change test and 10% for the Flo Design test.
  - Persistent misconceptions
    - 70% of teachers think that throughout Earth's history, average global temperature has been colder when compared to modern times (climate change test).
    - 35% of teachers do not know Faraday's law (flo design test).

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Conclusions

- Teachers utilized all scientific and engineering practices.
  - Teachers had most difficulty understanding systems (e.g. climate and human systems)
- Teachers are submitting their STEM units. Faculty will assess (e.g. constant comparative methods) the extent teachers embed scientific and engineering practices as part of their STEM units.

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Conclusions

- Based on a project evaluation survey, teachers felt most strongly about…
  - Improving their content knowledge of climate change
  - Understanding the new scientific and engineering practices
  - Collaborating in interdisciplinary teams

Resources

- InTeGrate (the climate change activity is still in development)
  - http://serc.carleton.edu/integrate/index.html
- Problem-based Learning Project
  - http://www.pblprojects.org/

Questions?