

PROBLEM-BASED LEARNING
IN THE SCIENCES

It's Electrifying!

An Exploration in Water-Based Alternative Energy

NAGC Curriculum Award-Winner

Teacher Manual

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Problem Narrative:

The Storyline for *It's Electrifying!*

Ideally, the direction of a Problem-Based Learning unit is decided through the questions students ask. To some extent, this is made manageable by the structure of the opening scenario presented during Problem Engagement. The opening scenario is carefully designed to point students in the direction of some predictable questions. For example, it would be hard to avoid asking about the energy needs of the people in Virginia Beach or about how the three forms of water-based alternative energy operate. The narrative below and the lesson plans in this unit respond to these more predictable questions and address other desirable learning outcomes. They also provide a helpful guide for teachers new to PBL. Experienced PBL teachers are encouraged to use this unit as a framework, selecting lessons that fit the students' questions (and, as above, many should fit) and adding other lessons to address other questions.

Problem Engagement

It's Electrifying! could begin in one of two ways. In the first option, the unit starts with the activities included in the *Electrical Engineer License Renewal* online program. This option is best for teachers who are concerned about their students' background knowledge of atomic structure and electricity generation. The second option is to start with the opening scenario memo and integrate the *Electrical Engineer License Renewal* activities into Inquiry and Investigation, which is more consistent with PBL philosophy.

Whenever students receive the memo, they learn that they are in the stakeholder role of the engineering team for an alternative energy company called Energy Everywhere, Inc. The opening scenario of the problem takes the form of a memo from the CEO of the company. In the memo, the CEO states his intention to move away from solar energy into other branches of alternative energy. He asks the engineering team to research options and prepare a proposal outlining the best ocean-related alternative energy option for the Virginia Beach Alternative Energy Initiative (VBAEI). The VBAEI is looking for a way to meet the federal goal of producing 20% of its energy via alternative energy options, and the CEO sees this as an opportunity to create a footprint for the company using a different form of alternative energy.

Questions Students Should Ask

- What is Energy Everywhere, and what do they do?
- What is alternative energy?
- Why is alternative energy important?
- What are the basics of energy production?
- What alternative energy options are available in the Virginia Beach area?
- What is the potential energy production from wave, tidal, and wind energy?
- What issues do we anticipate might arise from this emphasis?
- What do we need to know about the Virginia Beach area as we consider wave, tidal, and wind alternatives?
- What more do we need to know about this 20% increased production goal?
- How energy is generated now?
- Why is Virginia Beach responding to this initiative?
- What is innovation?
- What needs to be included in the proposal?

Inquiry and Investigation

Students conduct background research on the Virginia Beach area to see what kinds of alternative energy might work in that region. They use GIS maps (geographic information system maps) to assist them in determining coastline features, wind speeds, tidal patterns, and other logistical features necessary for alternative energy to be effective. In an optional activity, they construct and test their own mini-generators to improve their understanding of how electricity is created.

Questions Students Should Ask

- Which questions did we want to answer first?
- What are the best methods of finding answers to those questions?
- What will we do if we can't find the answer?
- How are we going to record our information?
- How should we go about updating each other on what we've learned?
- What equipment and/or materials are necessary to generate energy from the source we are researching?
- How much energy will this source realistically produce?
- How does this compare to nonrenewable resources?
- What is the estimated cost of the alternative energy source we are researching?
- How long will it take to recoup the cost?

Soon students will decide (or could be encouraged) to separate into groups based on one of the three alternative energy options—wave, tidal, or wind. As they work, they will gain a more in-depth understanding of that energy source. They will keep a running list of the advantages and disadvantages of the energy source they research using the Alternative Energy Research Chart.

Just as things seem to be getting clearer, students receive letters of protest. Each letter targets one of the three alternatives under consideration: surfers don't like wave energy, sea turtle activists don't like tidal energy, and homeowners don't appreciate the aesthetics or the environmental damage caused by offshore wind turbines. The novice engineers realize that regardless of the form of energy they choose, someone will be disgruntled. In their Problem Logs, they are led to consider the dilemmas that occur when one form of "good" (alternative energy) is in conflict with another form of "good" (endangered animals, tourism income, the environment).

Questions Students Should Ask

- What are the issues raised in the letters?
- Why are these people upset?
- What new questions does this information raise?
- Will we be able to satisfy everyone's concerns? How do you think engineers working in alternative energy address issues like these?
- How should we go about addressing these issues?
- Why do you suppose people are responding this way to a positive innovation?
- What is the relationship between innovation and public perception? How does this awareness affect your thinking about what we need to do?

After a little more research targeted at responding to protesters, students assemble to compile their research in a comprehensive chart. They consider which forms of energy are most important or most feasible for the Virginia Beach area. As the discussion concludes, the students are informed that they will have to come to consensus about which form of energy they will support the next day.

Problem Definition

Students work together to select a single option to pursue. This is different from traditional classrooms in which students often work in groups, with each group pursuing the solution of its choice. However, this is consistent with professional practice (for example, at NASA, many rocket models may be considered, but ultimately only one design is put into full production). Learning how to come to consensus is important to 21st-century learning; this allows the students, not the teacher, to decide what option should be the focus of their report.

To help them come to consensus about the type of alternative energy source they will pursue for their proposal, the students are presented with definitions that distinguish between consensus, agreement, and majority rule. They are then guided through a structured process that ensures that crucial concerns are addressed, regardless of the option they select.

Once a decision has been made, the students will discuss and identify the issue (which is fairly clear in this case) and constraints within the problem. Next, they will articulate the problem they must solve by creating a problem definition statement using the form:

We will (issue), making every effort to (constraints).

Example 1: *We will create a successful proposal for tidal energy, making every effort to protect marine life and maintain vacation beachfront.*

Example 2: *We will create a successful proposal for tidal energy, making every effort to minimize the cost to consumers and disruption of the local ecosystem.*

Questions Students Should Ask

- What is the primary issue we're facing?
- What are some (logistical, political/interpersonal, personal) constraints?
- How important are the concerns relative to the benefit we could bring to the community?
- How successful is our proposal likely to be if we fail to address the concerns at all?

Problem Resolution

At the end of Problem Definition, students selected a single form of energy as the focus of their proposal. Problem Resolution begins with some additional research time for the class to broaden the scope of their knowledge about the form of energy they selected. A number of optional kickers are included in this section that direct students to specific comparisons between different forms of energy. In the kickers, students are asked to: (1) distinguish between wave and tidal energy, (2) describe how turbines work in wind and wave energy, and (3) discuss why they think their form of energy is superior to solar energy. Any one of these kickers can be introduced to ensure that students have the necessary depth of understanding about the type of alternative energy they selected.

Finally, students gather to consider the options for their proposal. Location, structure, and methods of responding to concerned residents should all be addressed in a comprehensive proposal, along with other criteria and potential obstacles listed in the problem definition and the initial memo. Included in this section is a list of websites with directions on how to create a model or simulation of each kind of

alternative energy (an energy-generating windmill, a model tidal barrage, a simulation of waves and wave energy) so that students can present something concrete as a part of their presentation. For each form of energy, at least one website relies primarily on readily available materials.

Questions Students Should Ask

- What will the short- and long-term costs be to pursue this type of alternative energy (including personnel, equipment, community outreach, etc.)?
- What will be the biggest challenge to pursuing this type of alternative energy?
- What are some possible solutions to the problems we may face?
- What are the greatest benefits of this type of energy, and how can we educate the community about them?
- What kind of timeframe will it take to complete this project?
- How did we decide on the location for the placement of the alternative energy source?
- Are there any environmental components that need to be taken into consideration before we begin the project? If so, how will we address them?

With this information in hand, students proceed to preparing the written proposal and the oral presentation to present to Energy Everywhere's CEO and/or potential funding sources. Tasks associated with preparing the presentation can be divided among groups of students in different ways, including division by format (written report, visual demonstrations, etc.) or by report section (why one form of alternative energy was selected over the others, how the selected form works, etc.). The groups should continue to touch base with one other to ensure that their content is coordinated and accurate.

The presentation and written proposal are the culminating products for the unit.

Problem Debriefing

Students are given one final task to complete for the CEO, during which they will reflect on the content they learned as they worked through the problem. They also will have an opportunity to reflect on the Problem-Based Learning process. Teachers may opt to invite guest speakers who work as experts in the field of alternative energy to present to the class during this last phase of the unit.

Problem Engagement

Energy Everywhere




Minimum Recommended Time: One class period

Goals and Purpose:

- Introduce students to the problem.
- Help students identify important questions.
- Develop issues on the Learning Issues Board.
- Prioritize learning issues.

Grouping: Pairs for think-pair-share activity; whole group for discussion; individual for reflection

Opportunity for Differentiation: Differentiation based on the learning modality in the Reflective Moment (visual-auditory vs. written)

 Materials	 Problem Log	 Teacher Reference
<p>Included in Unit</p> <ul style="list-style-type: none"> • Memo from the Energy Everywhere CEO • Learning Issues Board • Reflective Moment • Interview Transcript <p>Additional Materials</p>	<ul style="list-style-type: none"> • Learning Issues Board • Reflective Moment • Interview Transcript 	<ul style="list-style-type: none"> • Sample Learning Issues Board

Summary:

Students receive the opening scenario that introduces the problem. A memo arrives from the CEO of Energy Everywhere. The students read the memo and then complete the Learning Issues Board, identifying the first set of questions to research.

Things to Do Before Class:

1. Read through the materials for this lesson, and consider what questions to ask to draw out issues directly associated with the problem.
2. Download, print, and make copies of the memo from the CEO of Energy Everywhere.
3. Prepare a Learning Issues Board on a whiteboard, smartboard, or LCD projector for whole-class discussion. Alternatively, set up a wiki for an online Learning Issues Board.
4. Use the website resources in Appendix A to prepare folders of information that students can use to begin their research at the end of class, time permitting.

Things to Do During Class:

1. At the beginning of class, distribute the Energy Everywhere memo. Once students have had time to read the memo, have them conduct a think-pair-share activity in which they pair up and use the Learning Issues Board in their Problem Logs to record facts from the memo that seem particularly important, their hunches about what's going on, and any learning issues that arise. Assure students that all questions are welcome, from questions about vocabulary to larger questions about the problem.
2. As a whole group, have the students share what they know and what they want to know more about after reading about the problem. Help the students distinguish between their hunches about the problem (i.e., "The mayor is worried about the cost of energy") and the facts presented in the memo. Record student responses on the class copy of the Learning Issues Board. Have the students copy the information into the Learning Issues Board in their Problem Logs.

Key Questions:

- *What seems to be going on here?*
- *What is our role in this situation?*
- *What useful information is provided in the memo?*
- *What do we know about the current situation? About our task? About the area that we are supposed to serve?*
- *What does the memo say about our timeline?*
- *What questions do you have about our task?*
- *What in the memo is unclear to you?*
- *What do we need to know to make progress on our assignment?*

3. As the discussion continues, help students refine their questions so that they are specific and researchable.
4. After students have finished listing their learning issues, direct them to engage in another think-pair-share to identify the two or three questions they need to answer first in order to make progress. As a class, discuss the students' rankings, expanding the list to include five top-priority questions.
5. Help the students develop a plan of action to find answers to their high-priority questions. Encourage them to think beyond using the internet as a means of conducting research. Prompt them to consider who they could interview, what visual resources they could use (including maps), or what other ways they could learn about the problem.
6. If you plan on teaching the lesson on electricity (see *Watt in the World?*, p. 45), ask the students if they think a refresher on the nature of electricity would be helpful, especially since they are supposed to be considering how to create energy. If they answer in the affirmative, be sure to include that lesson in the unit. If not, you may skip that lesson.

Key Questions:

- *How can we go about finding information to answer our questions?*
- *Who are some people we could contact?*
- *What could we look at to help us understand (the geography of Virginia Beach/energy use in Virginia Beach/etc.)?*
- *Would a demonstration on electricity give you some helpful background knowledge?*

7. At the end of class, have students complete the Reflective Moment in their Problem Logs, or assign it as homework. This Reflective Moment requires students to watch a video on the internet. If students do not have access to video streaming for this assignment, have them read the printed transcript that appears in their Problem Logs immediately after the Reflective Moment.

Notes: The Reflective Moment introduces students to the lives of engineers working in alternative energy production. Students could either watch one of two video links to interviews or read a transcript of one of the interviews. The transcript is edited for length but is still three pages long, so students will need reading time if the assignment is to be completed in class. Students who use the video option will have more details to draw from for their response.

The Reflective Moment asks students to report what they found interesting about the video or reading. If the students can't think of anything, have them review it again, and give them another chance to find something. This is an exercise in intellectual curiosity, building students' willingness to find something interesting even if they don't find the content inherently interesting.

Energy Everywhere

To: Engineering Team

From: James Nga, Energy Everywhere, Inc. CEO

As you know, recently we have moved our parent company, Energy Everywhere, Inc., from solar energy to a more diverse set of alternative energy options. This expansion could be solidified by landing a substantial contract that would provide alternative energy to a significant portion of a community.

In 2010 the Virginia Beach Alternative Energy Initiative (VBAEI), created by the mayor of Virginia Beach, Will Sessoms, published its plans for developing alternative energy use in and near the city. The report contains six goals, most of which have already been thoroughly designed and planned. Goal 6, *Increase indigenous energy production by twenty percent by 2025*, however, is still a work in progress. This is where we come in. Energy Everywhere has an opportunity to help shape the future of energy use in the Virginia Beach area. Because the VBAEI is currently working on designing its plans to meet Goal 6, it is accepting proposals outlining the best, most cost-effective form of renewable energy to introduce to the region.

Your job is to develop a proposal for submission convincing the VBAEI that Energy Everywhere is the only company that can effectively achieve Goal 6. As you work, keep in mind that the proposal is for a coastal region, so you should pay special attention to exploring the viability of ocean-related sources of alternative energy, especially wave, tidal, and wind electricity production. I suspect that we will have some significant competition, so it is important that the proposal be both innovative and feasible. We want to be a part of a realistic transformation of energy production.

As we investigate which option(s) to choose, we will have to consider logistics, cost, and public acceptance. A project like this would open an exciting door for both our company and the state of Virginia since it would be one of the first large-scale ventures of its kind on the East Coast.

Your proposal is due two weeks from today. However, I have an initial meeting with the VBAEI early next week, so I may need an update before the proposal is due. Keep in mind that one of the tenets of this company is our dedication to innovation. It would be wise to ensure that your presentation reflects this philosophy.

Learning Issues Board

Hunches:

What We Know	Learning Issues	Plan of Action

Reflective Moment: Engineers and Energy

You have been asked to step into the shoes of an engineer who works in alternative energy. Watch one of the videos, or read the description provided on the following pages, and describe the *attitudes* and the *skills* required to be in this field of work. What did you find interesting about what you saw and/or read?

A quality response: (1) addresses the question, (2) stays on topic, (3) is plausible or reasonable, and (4) gives enough detail to make your ideas clear.

Video Options:

www.iseek.org/industry/green/careers/energy-engineer-video.html

www.iseek.org/industry/green/careers/wind-developer-video.html

Written Option:

Attached transcript

Who Are YOU?

*Meet Tanuj Gulati, a senior energy engineer for
Energy Management Solutions (EMS), Inc.*



Please share your name, title, and a description of your job responsibilities.

My name is Tanuj Gulati. I'm a senior energy engineer for Energy Management Solutions, Inc. Our company does energy audits and energy conservation analysis for commercial and industrial customers. For energy conservation projects, we have to first find out what the customer is looking for. That is, what can we do to help them make the best energy conservation decisions related to their projects? We usually start by visiting people on the floor, talking to them, and asking questions about what they need in order to make this building more energy-efficient. Then we come back to the office, do the calculations, put spreadsheets together, and determine which products in the market are the best fit for that particular project.

...Once that is done, we present our findings and recommendations to the people who will be making the decision. If they choose to move forward with the project, that's great. If they don't, they may tell us that they're not comfortable with some aspect of the project in particular. In that case, we'll revisit the topic to ensure they have all of the information they need and want. Most of the time, after two or three back-and-forth meetings, the project will move forward.

The best part about this job is when the project gets done and the customer is happy. And we are happy to see that they listened to our recommendations, that they completed their project, and that they were able to get the energy savings they were expecting.

How did you get started working in this field?

In 1999, I finished my bachelor's degree in mechanical engineering. After that, I was hired by Chemical Industry in India. While I was working there, I noticed I was interested in how I could make their process flow better—that is, how I could make the movement of material and labor more efficient. That's when I realized that I wanted to be in the field of making businesses more energy-efficient.

In 2002, I came to the United States to get my master's degree in mechanical engineering. While I was finishing up my master's, I was working on a fuel cell, which is a renewable energy source. That work brought me closer to what I wanted to be doing....

Problem Log

In 2005, the Industrial Assessment Center at the University of Louisiana put together a conference for commercial customers in New Orleans. The owner of Energy Management Solutions was one of the presenters. I was facilitating and heard his presentation. I knew this is the field I would like to be in, so I gave him my resume.... About one month after I took my technical test, I was flown to Minnesota for a face-to-face interview. A week later, I was offered an internship. A few months later, I was a full-time employee. I am still working for Energy Management Solutions and love every bit of it.

What sort of training or education do you have?

I have a bachelor's and master's degree in mechanical engineering. I worked for the Industrial Assessment Center for a year and a half, and I have since become a certified energy manager, certified energy auditor, and certified lighting efficiency professional. All three are certified by the Association of Energy Engineers.

That's my formal experience and educational background, but we have to keep doing things to remain knowledgeable in a changing market. For instance, I have attended a lot of trainings regarding compressed air, HVAC, refrigeration, steam, and motors. I also read related magazines and go on websites like the one for the Association of Energy Engineers and for the U.S. Department of Energy to keep myself on top of new technologies. Additionally, I sometimes go to energy design conferences.

What sort of tools, machines, or equipment do you use regularly?

I use a laptop and cell phone, as well as GPS devices, thermometers, thermo-sensors, data loggers, light meters, and infra-red cameras.

I always have a light meter with me to determine lighting levels. This helps determine how we can maintain the same lighting level but with more efficient lighting or lets us know if those lighting levels are efficient as they are. I also always carry a thermo-gun with me. It's a sensor to see whether parts of a building may have energy leaks....

Cell phones and laptops are always handy for us. Sometimes we sit down with a customer to process the data right away. We can do some spreadsheets so we have an idea of what our recommendations will look like and what the energy savings calculations will look like to give the customer an estimate of what's going on.

What skills or personal qualities are good for this job?

...you have to be a good communicator. You should be persuasive for people to realize what you have to offer. Do remember this: customers will be investing a lot of money in their project....

You should also have good mathematical skills. You should be good in Excel so you can easily pull up reports and clearly communicate. You need to communicate, "This is what I'm saying, and this is *why* I'm saying it. These are your pay-backs, and here are your projected energy savings in the next year."

So you have to be a good presenter, persuader, and communicator. You have to help them make decisions. You can't just give them a spreadsheet and move on. You have to follow up. If there is a question, you need to give them an answer. If you give them a report and it sits on their desk, the project might not happen. If you give them a report and follow up to see what's going on, they might tell you, "I'm not comfortable because I'm not sure if this will work." Then we come back with more information that the customer can look at to help him better understand what we're suggesting. He can look at it, read it, and feel comfortable that what we're suggesting has been done before and has a proven track record.

What do you enjoy most about your job?

I enjoy that I get to wear different hats every day. I get to visit different people, different facilities. Sometimes I'm in a food processing facility, sometimes I'm in a city building, and sometimes I'm in schools or shipyards. We get to travel a lot. We get to see different places. Every place that we visit has an entirely different scenario.

The other thing that I like is talking to the customers and helping them make good decisions about energy conservation....

How does your job benefit the environment?

It is a direct impact on the environment: lower energy usage results in lower greenhouse gases, which positively impacts the environment. The benefit is very direct.

Are there any common misconceptions about this type of work?

Until recently, energy conservation used to be a topic that was almost an after-thought. But since the economy has changed, people have started to worry more about the profitability of their company. They're looking into forecasting their future profit and how their industry would be doing in the future. Electric and gas rates are going up, and energy is getting expensive. So this type of work is no longer an after-thought. It's seen as more relevant and important.

Also, people used to think that anyone can do energy audits, and that's not true. You have to know what you're recommending. You have to know what's going on. You have to be familiar with the business....

What is your advice to someone interested in this field?

...Internships are always helpful. We have people approach our organization for internships, and for the past five years we've had interns every year. Some of the people I have personally given recommendations for are now in this field. In fact, this morning we interviewed a woman who might intern with us. If it works out, she will start working for us soon.

Any final thoughts you'd like to add?

I'm passionate about my job because I like wearing different hats every day. I'm not just sitting at my desk doing the same thing every day. I'm visiting different customers, looking at different projects, looking at different problems. And different people try to save energy in different ways. Some try to use less water; some try to use less gas; some try to use less electricity. And that makes it interesting....

But what I like best about my job is when customers complete projects using my recommendations. It's a great feeling when you walk into the building after the project is done and the customer says, "Hey, Tanuj, thanks for telling us about this. It worked, and we love it!"

Sample Learning Issues Board

Hunches: Energy is getting too expensive. The mayor wants to reduce the cost of energy. Solar energy hasn't worked for our company. Our boss thinks other forms of energy will be more profitable.

What We Know	Learning Issues	Plan of Action
<ul style="list-style-type: none"> • We are an engineering team. • Our parent company is Energy Everywhere, Inc. It has moved from solar energy to more diverse alternative energy options. • It would like to win a contract providing alternative energy to a portion of a community and is looking at Virginia Beach, VA. • The VBAEI is working on planning the best way to increase indigenous energy by 20% by 2025. • The CEO wants to submit a proposal outlining the best alternative energy option for the area. • A project like this would be the first large-scale venture of its kind on the East Coast. • The company wants to be a part of transforming energy production. • We will have tough competition. • We are supposed to consider ocean-based alternatives (wave, tidal, wind). 	<ul style="list-style-type: none"> • What is Energy Everywhere, and what do they do? • What is alternative energy? • Why is alternative energy important? • What are the basics of energy production? • What alternative energy options are available in the Virginia Beach area? • What is the potential energy production from wave, tidal, and wind energy? • What issues do we anticipate might arise from this emphasis? • What do we need to know about the Virginia Beach area as we consider wave, tidal, and wind alternatives? • What more do we need to know about this 20% increased production goal? • How is energy generated now? • Why is Virginia Beach responding to this initiative? • What is innovation? • What needs to be included in the proposal? 	<ul style="list-style-type: none"> • Search online to find out more about VBAEI. • Email the mayor's office to find out more about the Virginia Beach initiative. • Talk to an engineer about different forms of alternative energy. • Look on the internet to learn about wave, tidal, and wind energy. • Conduct a simulation on electricity production. • Find maps of the Virginia Beach area.

Bold items represent students' top priorities for research.