MAKING SENSE OF THE DEEPWATER OIL SPILL DISASTER

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Problem-based learning is an important pathway for students when trying to develop conceptual understanding, build skills, and master content knowledge. A sense-making problem-based task is

- **Authentic** (has life-related, historical precedence and meaningful applications; is collaborative; and/or requires multiple perspectives)
- **Open-ended** (has no single, right answer or solution pathway)
- **Data rich** (makes sense of real-world contexts using quantitative and qualitative information and collection strategies)
- **Complex** (uses many skills)
- **Interdisciplinary** (allows for differentiation, multiliteracies and cross-curricular connections)
- **Assessed with a rubric** (clarifies expectations)

Authenticity in learning is becoming increasingly important as today’s students are not “buying into” school just because it’s there! Today’s high school students have learned firsthand (thanks to the COVID-19 pandemic) that science is not static and knowledge is not reserved in a single place or preserved by a single group of people. Students have survived and observed how uncertainty works and understand that truly scientific methodologies are data-informed, not data-driven. They understand that most trustworthy scientists acknowledge these constraints. Data help paint a picture of problems that are emergent and must be revisited over time. Tragic moments in human history are perfect contexts for sensemaking in the classroom. Thinking about the difference between events that are human-made, natural, or some combination of both allows us to think more deeply about how and why designed solutions are necessary. Authentic learning can be achieved best through problem-based learning. Presenting students with a problem-based task at the beginning of a unit of study builds a felt-need in students to learn the desired curriculum content. In our experience, teachers have offered students culminating projects to complete after they’ve taught specific content. Instead, we propose a need to present students with well-constructed problem-based tasks up front. Using oil spills as a scenario and defining context for problem-based tasks and inquiry, we developed focal questions that allowed students to expand their thinking about chemistry, Earth resources, and historical contexts that tie science standards (HS-PS1-4; HS-PS3-2; HS-ESS3-1, HS-ESS3-2; HS-ETS1-1; HS-ETS1-3) to other content areas.

**Interdisciplinarity of oil spill investigations**

At the beginning of the 2021–2022 school year (coming out of a year of online learning), we recognized the need to present chemistry in a broader context of problems—as interdisciplinary and historically responsive. The general expectation that all students can develop models “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” (NGSS Lead States 2013) grew as our department extended an action research project and book study of Muhammad’s (2020) *Cultivating Genius* into classroom activities “post” pandemic. We wanted to design learning that used easy-to-get materials and could be done in a hybrid context (with some students in class, others online), in a traditional lab setting, or independently. We wanted all students to make sense of chemistry in the context of materials, natural resources, and design.
solutions while still honoring the imperative for social consciousness and truth-telling to combat misinformation.

The remainder of this article describes learning activities that use a PBL framework (authenticity, open-endedness, complexity, interdisciplinary, data richness, and clear assessment) for sensemaking in chemistry. A group of chemistry teachers has been modifying lessons for the last 12 years using information about the Deepwater Horizon oil spill of 2010 as it emerged, mining qualitative and quantitative data from journalistic photo essays and the National Oceanic and Atmospheric Administration (NOAA) and Environmental Protection Agency (EPA) websites (Activity 1). Students create and deconstruct a simulated oil spill using household materials to model oil fractions. In Activity 2, they mimic the spill and clean-up strategies researched online using available gallery photos and data from media outlets and government agencies. Quantitative data collection/analysis was limited to available datasets from the EPA and NOAA generated during the active Gulf of Mexico crisis in the 2010s (Activity 2).

Finally, students summarize their learning at various points of the year in a project of their choosing that demonstrates their “KNOW-ledge” (Activity 3). As an extension to the learning, students have opportunities to think about natural resources and their distribution around the world. As a means of differentiation, students have the option to consider fiction and non-fiction texts and/or produce work products that are showcased as stories, videos, podcasts, websites, reports, or presentations. These activities capitalize on the pursuit of genius and joy described by Muhammad (2022), capturing the ways that science is communicated to the public as they build their own science identity and skills. This develops criticality in students where they learn to consider all media as potential sources of technical information (or misinformation).

Disaster chemistry and fossil fuels
Finding energy sources that minimize pollution is a global challenge that considers the relationship between human needs, human activities, the inevitable threat of oil spills, and the various opportunities for technology and other engineering-designed solutions to help solve these problems. Limited access to fossil fuels—a nonrenewable energy source—means that extraction is expensive and often controversial. Availability of natural resources like oil dictates many human activities, including development (HS-ESS3-1). In our chemistry classes, we integrate these Earth science topics into our curriculum at the start of the year by exploring different types of fossil fuels and the relationship between molecular mass (matter) and energy—an idea that is revisited throughout the year (combustion reactions, stoichiometry, enthalpy). Language used by oil industry professionals becomes the context for student exploration and investigation. Working in collaborative groups of three to four students with clearly defined roles and responsibilities, various sources of information and media help students make sense of oil spill disasters. Through data analysis, modeling, and research, each member of lab investigation groups is assigned a role and expected to complete specific management and academic tasks within the group. This ensures interdependence among students and individual accountability.

Management tasks/responsibilities
• Materials and time keeper
• Photographer
• Technician
• Recorder/Scribe

Academic tasks/research responsibilities
• Vocabulary checker
• Fact checker
• Calculator
• Researcher

All students in the lab group contribute to a shared document that is monitored for activity and graded based on contributions by each group member.

Activity 1: Oil spills—data analysis (75–90 minutes, 2 class periods)
In Activity 1, students use different types of data as evidence of a real-world problem. Quantitative measures are supported by visual representations on maps provided by NOAA and the EPA. In-class discussions of data categories allow for real-world application of measurement topics that involve significant figures and dimensional analysis (Table 1; see Online Connections). Focus question: What evidence exists in the photos/news stories to support the claim that limited availability of fossil fuels poses a threat to living things and requires new systems to monitor and extract natural resources?

Resources for qualitative evidence: Photo essays
• Watch 10-year anniversary news story by CNN; Compare video retrospective to archival photos of BP oil spill available online: https://www.cnn.com/2020/04/20/world/deepwater-horizon-spill-anniversary-fish-study-scn/index.html

Resources for quantitative data: EPA & NOAA datasets (trajectory studies)
• EPA data: [https://edg.epa.gov/metadata/catalog/search/resource/details.page?uuid=%7B84338832-4C9E-4152-933E-E127E27D70EE%7D](https://edg.epa.gov/metadata/catalog/search/resource/details.page?uuid=%7B84338832-4C9E-4152-933E-E127E27D70EE%7D)

**Discussion questions**

• What kinds of data were collected during the BP oil spill? Do the data reported in news stories and social media reflect the standards of precision/accuracy used in scientific reports? Why or why not?

• Why are photos an important resource in data collection and modeling? (Figure 1)

NOAA refers to weathered oil samples as light, heavy, and medium. A discussion of viscosity as a bulk property of oil can be tied to other chemical and physical properties. In 23 columns and almost 6,700 rows, key data about the Deepwater Horizon spill of 2010 are organized and serve as a model of science and engineering practices. From these data, students are able to use units as mathematical representations of samples. They are also able to apply scientific principles in the interpretation of the data and understand how/why the reporting agencies communicate technical information at the molecular level. One of the group roles is to develop expertise with academic vocabulary. Words like *toxic* and *hazardous* are contextualized using information used to describe petroleum products’ effect on living organisms. Are these designations warranted, especially when the public regularly misinterprets information? Use information available in MSDS/PubChem resources to determine chemical and physical properties of at least two materials, including molecular formula, and chemical safety information. Cite your information as a footnote at the bottom of your page.

• Discuss as a group what the most important data are for mitigating anxiety in the public. Explain your choice.

• Create a summary table of relevant data for communicating findings to the public about which data points you think are the most important for them to know.

• Summarize findings from your BP oil spill model/simulation to explain the value in predictive modeling and projections in research based on NOAA maps for emergency management of oil spills.

Finally, if there are inconsistencies in the data, students are able to make sense of possible human error and/or bias in a dataset. For example, Table 1-C (see Online Connections) shows how neither county nor zip code are reported for a tar sample. However, the data are labeled with a location, latitude, and longitude. Students then work in collaboration with peers to provide explanations for the data as a claim-evidence-reasoning activity and cross-check with other published reports (e.g., Sammarco et al. 2013). The investigation of latitude and longitude provides evidence to suggest the tar sample was collected at a beach in Pensacola, Florida. Reasoning for the data gaps may include explanations related to the limits of citizen science, tar having different properties than weathered oil, or something else.

Students are challenged to critically examine the information provided by the agencies and other consumer websites that discuss the spill. As a purposeful exercise in information literacy, students are prompted to look for and review updates for changes in data and cross-check (fact check) information provided by diverse sources (RST 11-12.7).

At various times of the year, the data are revisited. As students learn specific reaction types and properties of substances, they continue to build understanding about the various ways technical information is conveyed to the public. They use these understandings to reflect on the nature of global challenges like pollution and climate change. One example of an in-class activity is exploration of molecular structure and intermolecular forces that determine bulk properties like boiling point and vapor pressure. Students learn that larger hydrocarbons have higher boiling points and vapor pressure as they research compounds using websites like PubChem ([https://pubchem.ncbi.nlm.nih.gov](https://pubchem.ncbi.nlm.nih.gov)) and MolView ([https://molview.org](https://molview.org)).
Activity 2: Simulated oil spill and cleanup (90 minutes–2 hours)

Taking a “storyline” (Sadler and Van Tassel 2022) approach to oil spills, Activity 2 examines the behavior of simulated fossil fuel (made with cocoa powder and oil) by creating models of simulated oil fractions and describing the relationship between chemical and physical changes as a way to make sense of the real-world problems that define oil spills. Building on the EPA definition for crude oil available online, students investigate the behavior of their mixtures in water and try to remove it with various objects (paper towels, cotton swatches, fabric swatches, plastics, feathers), techniques (filtration), and cleaning agents (powdered and liquid soap) as a way to perform similar experiments as those done by scientists and citizens in the Gulf area in the 2010s.

Safety

Although materials used to make simulated oil are edible, students are warned against eating in the lab and required to wear safety goggles. Use small beakers (25 ml) or 3-ounce disposable cups to minimize waste. Cleaning agents used for the investigation are liquid soap and scent-free powdered laundry detergent.

Tasks to complete during the lab investigation:

• Make three different consistencies of cocoa-oil mix to mimic the different types of fossil fuels (by “thickness”) based on perceived density and viscosity.

• Make observations about how each sample looks and behaves. Create diagrams to represent your mixture. Take pictures and maintain observational notes in your lab notebook (Figure 2).

• Add each sample to the “basin.” Make observations about how each sample behaves in water. Diagram or take pictures to show behavior.

• What happens when a feather gets oil on it? How did the other materials clean up the oil? What happens to your simulated “boat” and other selected clean-up materials?

• What are the best materials (additives) for cleaning up the oil? What are the potential challenges to using these materials in an actual case of emergency management?

• How well did the cocoa-oil mixture simulate crude oil fractions/fossil fuels?

• How did the shape/size of your basin impact the results you saw? (Figures 3 and 4)

Formal Lab Write-Up

Create a formal lab report using a shared document to demonstrate understanding of the properties of materials used to model the real-world disaster of a fossil fuel spill. Use lab notes and analysis questions to create a document with the following sections:

1. Context of the problem based on primary source research, including a statement about the purpose/experimental goal of the lab; include reflection based on EPA data

2. Key terms/ideas with annotations (brief description of meanings from a chemistry perspective)

3. Materials and procedures

4. Data and observations (include photographic evidence of inquiry)

5. Analysis/Calculations

6. Conclusion paragraph that provides a description of errors, suggestions for changes in the procedure, and details about how the goal was met (or not). If the goal was not met, why? Pose at least two questions to explore potential topics for further investigation.

Reference/additional reading section with sources consulted for additional information in APA style

FIGURE 2

Directions based on “consistency.”
FIGURE 3

Sample oil fractions on wax paper.

Left: front view of simulated oil (cocoa and vegetable oil mix)  
Right: side view of simulated oil (cocoa and vegetable oil mix)

Comparison of simulated oil samples made with cocoa powder and vegetable oil demonstrates a property of liquid substances showing viscosity, surface tension/ intermolecular forces.

IMAGE SOURCE: AUTHOR.

FIGURE 4

Oil fractions in basin, student report.

NHRDE Lab group

Oil Spill Lab

1) E- Tap water unlike fresh water and salt water has been treated, meaning that it contains chemicals such as fluorine and chlorine.
2) E- Our Tar-like sample sunk to the bottom immediately and stayed clumped together. Our Cake mix sample sunk immediately to the bottom, while it was looser than the tar, it was still clumped together. Our brownie sample was very similar to our cake sample, only in that, it was slightly more clumped together, but not as clumped as the tar-like sample. Our syrup like sample sunk to the bottom immediately as well, but it broke apart and create little beads the rested on the bottom of the bowl that could be moved.

IMAGE SOURCE: STUDENT WORK GROUP.
Activity 3: Direct instruction, reflection, and policy recommendations (ongoing)

Activity 3 is ongoing and shaped by the remainder of the high school chemistry curriculum. Regional oil spills, local pollution, and natural hazards like hurricanes spark interest in environmental applications of chemistry to students’ everyday lives. Increased media coverage about pipeline construction projects and climate change also supports year-long investigations about fossil fuels and alternative energy sources. These topics allow students to reflect on early-year activities throughout the year allowing for differentiation by interest, skills, and work product.

Students with advanced technical skills and interest were invited to read a technical paper (see Sammarco et al. 2013) that uses the same NOAA/EPA data sets as an alternative and culminating assessment (see Backus 2023). Another student chose to analyze a French song about the oil spill (“Un Bateau Mais Demain,” https://www.youtube.com/watch?v=BM7gtz9oyAw).

One colleague built on the oil spill activities by conducting a problem-based learning project that explores thickness of oil films on water. Students calculate surface tension and surface area as a CER activity (Figure 5).

If interested in exploring other disasters, students could investigate claims presented in the media or news about “extreme” disasters and support or deny them based on evidence. Colleagues have also developed activities that investigate fossil fuels as home heating sources over time, comparing modern energy sources to peat, coal, and other fossil fuels (http://www.cyberphysics.co.uk/graphics/diagrams/energy/ancientsolar_electricity.gif), enthalpy of combustion (https://docbrown.info/page07/delta1Hd.htm), and petroleum chemistry (http://www.petroleum.co.uk/).

NOAA and other agencies have developed many tools for responding to emergencies created by human-made and natural hazards. The GNOME project (https://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/response-tools/gnome-suite-oil-spill-modeling.html) is an excellent source for students to interact with public data tools and resources.

Evaluating learning

Self-reflection and peer review are two necessary elements for sensemaking. Two rubrics are used to evaluate learning for these activities: The PEAS & Qs rubric (Table 3; see Online Connections) is a group accountability rubric used in peer evaluation and the KNOWledge rubric (Table 4; see Online Connections) is used for final projects that communicate scientific and technical information to the public.

FIGURE 5

CER oil thickness.

Guiding Questions:
Example 1: How can we accurately simulate and measure the thickness of an oil spill?
Example 2: How many liters of oil have spilled into the water? How can we accurately simulate and measure the thickness of an oil spill?

Claim:
Example 1: The thickness of an oil slick is an average of 0.51 cm.
Example 2: The thickness of vegetable oil is 0.273 cm. This figure is based off of the average thicknesses calculated for three different volumes of vegetable oil.

Evidence:
Example 1: The thickness of vegetable oil is 0.273 cm. This figure is based off of the average thicknesses calculated for three different volumes of vegetable oil.

Table 1: Container Dimensions, Total Volume

<table>
<thead>
<tr>
<th>Trials</th>
<th>Amount of water (mL)</th>
<th>Amount of vegetable oil (mL)</th>
<th>Length of container (cm)</th>
<th>Width of container (cm)</th>
<th>Total volume of all substances in container (mL)</th>
</tr>
</thead>
</table>

IMAGE SOURCE: COLLEAGUE LESSON PLAN.

PEAS & Qs

This general performance framework (PEAS & Qs; Barnes-Johnson and Johnson 2018) is based on five domains of evaluation: performance/products (models), effort, achievement, submission standards, and questions.

KNOWledge

The KNOWledge rubric is a self-reflection tool that asks learners to reflect on their own learning (first cited by Tebeck 2021). The basis for the reflection is a question: “What brings you to the edge of your learning?” In a metacognitive twist on the KWL graphic organizer, students are asked to take a “kaleidoscopic” view of the topic they studied. Like a kaleidoscope, they are asked to think about what they discovered that can only be discerned by taking a different perspective on the topic. They are also asked to consider what “new” thing they learned, what they found “obvious” about the learning, and what they “wonder” about after completing an inquiry or learning activity. The notion of self-reflection often serves as a basis for discussion and/or conclusions in a final report. Table 2 (see Online Connections) outlines how each activity supports 5E learning. Engaging students in conversations about human impact on the planet is necessary classroom discourse. Modeling complex problems in ways that are open-ended, authentic, data-rich, and interdisciplinary provide unique learning opportunities that are also historically responsive and take advantage of multimedia—perfect for sensemaking in the high school classroom.
ACKNOWLEDGMENTS

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ONLINE CONNECTIONS

Table 1. Data table headers: Weathered oil and tar sampling data for BP oil spill/Deepwater Horizon: https://tinyurl.com/md7x8ns4
Table 2. 5E timeline of learning activities: https://tinyurl.com/553vdueu
Table 3. PEAs & Qs rubric, general description of process rubric for peer review and self-check: https://tinyurl.com/b2858ydn
Table 4. KNOWledge rubrics: https://tinyurl.com/2ytk2mv8
Black gold—Valuable commodities (slide deck): https://tinyurl.com/4f825j8r

Additional resources for extended learning (Interdisciplinarity):
Science can be communicated using informational text and data (nonfiction) or fictionalized storytelling. Provide students with a choice of texts for exploring relevant topics about resource distribution including infographics and videos.
• New York Times interactive series
• Top 10 Worst oil spills (CER activity: What makes these the "worst" oil spills?)
• Petroleum chemistry (overview)
• Home heating with oil vs. gas (article)
• Coal classification (rank)
• M.I.N.E.R. Act of 2006 emergency response plans
• Extension: Centralia (PA) mine fires burning for more than 50 years
• New superabsorbent cotton developed in India
• Girl rising: Senna’s story about mining communities (Peru)
• USGS National Mineral Commodity summaries (2022)
• Alloys of the future (news)
• Wakanda solutions for climate change (https://time.com/5889324/movies-climate-change)

REFERENCES


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