Supporting Three-Dimensional Learning From Students’ Questions About Water With a Storyline Unit

By Gretchen Brinza, Katie Larson, Amy McGreal, and Michael Novak

We developed an open-source fifth-grade science and engineering unit on water, earth systems, and the structure and properties of matter, called Where Does Our Clean Water Come From and Where Does It Go After We Make It Dirty? using a storylines instructional model to support three-dimensional learning (Brinza et al. 2019; Reiser et al. 2021). A storyline is a coherent, multi-lesson unit where students see the science work they are doing as addressing questions and problems their class has identified as they explore phenomena. A storyline lays out a pre-planned sequence of questions, phenomena, and prompted discussions designed to support a progression that builds target science and engineering practices, disciplinary core ideas, and crosscutting concepts.

How can teachers help students raise productive questions from phenomena and investigate their questions so they develop the targeted science ideas? In this article, we share two specific strategies we use in the enactment and design of this unit: (1) The Anchoring Phenomenon Routine: Working with students to kick off investigations and (2) Navigation: Working with students to figure out next steps. An outline of the storyline, full lesson plans, as well as documentation of prior year implementations are shared in Online Resources.

THE ANCHORING PHENOMENON ROUTINE: WORKING WITH STUDENTS TO KICK OFF INVESTIGATIONS.

We begin this storyline using four elements in the Anchoring Phenomenon Routine:

• explore the phenomenon
• attempt to make sense
• identify related phenomena
• identify questions and ideas for investigations

Explore the phenomenon: The unit begins with the teacher asking students to help wash some items from the classroom (i.e., soiled containers, dirty glassware). After every student has had an opportunity to help, the teacher asks, “What did you do to get the items clean? What happened to the dirty stuff on/in the items?”

There are important similarities between the cleaning processes: scrubbing before/after, rinsing with clean water, dumping the “chunky” stuff into the toilet/sink’s drain first, using large/small amounts of soap, using clean water at the start, and producing dirty water that ended up in the drain.

Attempt to make sense: The teacher points out that all of their observations depend on water. Clean water is used to make something clean and to carry away the dirty stuff. This frames the two-part question that students are
asked to explain, “Where does the clean water come from and where does it go once we make it dirty?” As students share their initial models, there are many ideas of where their clean water comes from and where it goes once it hits the drain (Figure 1). The teacher observes that there are competing ideas—some students suggest the water comes from a lake, the ocean, or even wells/underground, and others from a treatment plant. Some students bring up the idea that water can be “filtered.” There are also competing ideas about where water goes. Students bring up ideas such as “sewer,” “landfill,” and also “ocean” and “lake” as destinations for the dirty water. The teacher celebrates all ideas here—there are no right or wrong answers at this time. This lack of consensus motivates the need for evidence, as students begin to question each other’s ideas.

*Identify related phenomena:* Next the teacher asks students, “We decided getting clean water and getting rid of it when it was dirty was really important for us in the classroom, but where else might we use clean water and make it dirty?” Students begin sharing related phenomena that involve using water in this way (e.g., commercial carwash, the laundromat, toilets, washing the dog outside). These connections lead the class to raise even more questions about the source for our clean water and where dirty water goes.

*Identify questions and ideas for investigations:* At this point, the students are asked to record their questions connected to the anchoring phenomenon, their classmates’ initial models, and the related phenomena list. As each student shares a question with the class and links it to questions others have asked, the class organizes their questions into clusters on a Driving Question Board (DQB; Weizman, Shwartz, and Fortus 2010). The DQB becomes a public representation of what the class wants to figure out to help explain the phenomena (Figure 2).

Next the teacher invites students to suggest information they need or investigations they could do to make progress on these questions. Students brainstorm a variety of investigations (Figure 3). Asking students what kinds of data they would need and brainstorming ways to make progress helps students see how the unit’s investigations connect to their own questions. Indeed, many of their ideas are already anticipated in the storyline.
Meaningful science work requires that students know and care why they are doing what they are doing, rather than just following instructions from the teacher or textbook. This begins with the Anchoring Phenomena Routine. Each subsequent step requires the Navigation Routine, connecting where the class has been to where they go next. The teacher invites students to consider what question they need to work on next and how they will investigate.

For example, at the start of Lesson 2, the teacher asks students to review the investigation ideas they identified for figuring out where dirty water goes, and then leads a whole-class brainstorm. The teacher draws on students’ ideas of using a camera flushed down a toilet or stuck in a storm drain to suggest analyzing a video from a plumber’s camera of a drain and pipes (see Online Resources). Analyzing this video helps the class figure out that the pipes don’t recycle water back into the building (a common conception), and instead go somewhere further away underground. This data source only takes them so far, so the teacher asks, “What data could we find to learn about where these pipes go beyond the end of the property? How could we figure out where everyone’s pipes go in their community?” Students typically suggest a map or blueprint of their community. Following these maps leads the class to discover that all sewer pipes converge at a wastewater treatment plant. ArcGIS maps help students uncover that there are big circular vats of dirty water and piles of waste at that site. The class uses this to develop a model to represent what they have figured out so far (Figure 4).

Although the teacher plays a key role in helping students refine these ideas, students are part of identifying what they need and how to make progress. Let’s see how that Navigation is supported by the teacher in another lesson. At the start of lesson 3, the teacher asks students to recall what they had noticed in the images of the water treatment plant. The teacher next has students consider what the facility might be doing with the vats of dirty water. Last, the teacher asks students to look back at their driving question board and ideas for investigations. This combination of looking back and looking forward illustrates another example of the teacher leveraging the navigation routine to launch a lesson.

Next, the teacher asks students to think about the purpose of storing the dirty water at the plant. What might they want to do with it? Students brainstorm ideas about this, which raises the idea that they might be trying to

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**FIGURE 3**
Alignment of student questions and ideas for investigations to lessons in the storyline.

<table>
<thead>
<tr>
<th>Student Question</th>
<th>Investigation Ideas</th>
<th>Lesson(s) Where Question is Addressed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Where does all our dirty water actually go?</td>
<td>-Go look in the sewer to see if the dirty water goes there.</td>
<td>2</td>
</tr>
<tr>
<td>-Go up a pipe to see if it doesn’t go there</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is there a “sewer” seep?</td>
<td>-Get a video footage of the seep.</td>
<td>2</td>
</tr>
<tr>
<td>-Get a “small detector” and look for similar seeps</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How does a sewer actually work?</td>
<td>-Run dirty water through various filters.</td>
<td>3, 4, 5, 6</td>
</tr>
<tr>
<td>-Put water under a microscope after the filtering process to see if it’s “clean.”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>What is a wastewater treatment plant?</td>
<td>-Go to the water treatment plant on a field trip</td>
<td>3, 4, 5, 6</td>
</tr>
<tr>
<td>-Get a camera inside the building (maybe through the pipes) to take pictures inside.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>What bodies of water are they connected to?</td>
<td>-Use a camera with GIS to see where the water goes or gets dumped into</td>
<td>7, 8, 9</td>
</tr>
<tr>
<td>-Follow the sewers to bodies of water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is there enough storage for sewage to go into these bodies of water?</td>
<td>-Research water usage online</td>
<td>9, 10, 11, 12, 13, 14, 15, 16</td>
</tr>
<tr>
<td>-Measure how much water goes into a day</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>How much water does the lake or river receive?</td>
<td>-Get a cup of lake/river water and take it to a scientist to test it for us.</td>
<td>17</td>
</tr>
<tr>
<td>-Examine it – look at its color and compare it to other water samples.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-Look at a water sample under a microscope.</td>
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<td></td>
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<tr>
<td>-Have a team of water divers look for clean lakes or Rivers that make the lake dirty.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-Follow the pipes to see if they lead to a clean lake/river</td>
<td></td>
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</tbody>
</table>
clean the water. When asked how they might do something like that, students suggest the idea of filters—something that was originally identified on the driving question board and investigation ideas the students developed.

The teacher now asks the entire class to consider whether students think that filters could be used to make water clean(er). Disagreement emerges around exactly how clean any filter could make water. The teacher then asks what the class would need to investigate that question further. While this brainstorming helps identify specific types of materials or filters the class would need, it also leads students to identify a new part of the problem to be addressed—they will need dirty water to study. That leads to discussion about how working with actual sewer water would be gross and potentially unhealthy. Students brainstorm how they could make their own “dirty water” with common items available in their classroom. The students become eagerly committed to (re)creating dirty water to represent the wastewater that is in the sewer, using safe, readily-available materials to represent food (e.g., cereal, pasta, graham crackers, sugar, salt, vinegar). They also decide to add in items to visualize or represent toilet sewage (e.g., toilet paper, food coloring, chocolate chips). Students are now deeply invested in planning and carrying out multiple rounds of investigation with various materials to filter their “dirty water.” They also are motivated to figure out what materials may still be left in the water after it is filtered (see Figure 5).

By the end of lesson 5, students will have figured out that pieces of matter that are larger than the hole in the filter get filtered out, but pieces of matter that are smaller do not (e.g., stuff that dissolved in the water). This model is supported by additional lines of evidence they collect about the “stuff” in the water (e.g., volume, mass) and the properties of it (e.g., color, odor), which helps students refine their concept of particle level of matter (see Figure 6). After trying to clean their water, they want to look at what is happening at a real water treatment plant in lesson 6.

**FIGURE 4**
A model representing what the class has figured out by the end of lesson 2 drawn in real-time by the teacher based on dictation from a remote class.

**FIGURE 5**
Student observation of dirty water.

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*Using navigation to help students revise investigation ideas*

What do we do with students’ ideas for investigations or design solutions that aren’t realistic to pursue? We find that we can often bridge from students’ original ideas to something realistic and relevant to the storyline. For example, after students figure out how to filter dirty water themselves in lessons 4 and 5, they want to see if something
similar is being done at the wastewater treatment facility. Students suggest a field trip, but it was not feasible due to age requirements for the site, lead time required, and cost constraints. Instead, we were able to develop alternate ideas with students: interviewing an expert, taking a virtual tour, or viewing a recording from a water treatment facility. Reinforcing this line of thinking and encouraging students to draft interview questions for a wastewater expert pushes students to engage in obtaining, evaluating, and communicating information before they view a recording of a narrated tour of their water treatment facility in lesson 6.

CONCLUSION

Implementing any storyline involves students as partners in identifying questions and problems, figuring out how to address them, and making sense of what they find. It involves attempting to balance figuring out target science ideas with granting students authentic agency. The Anchoring Phenomenon Routine provides real-world connections and opportunities for students to observe, wonder, and identify problems that they want to figure out how to solve. Navigation brings students in as participants in conversations about how to make progress. The sequence of lessons we highlighted from this storyline (lessons 1–6) show how we help students start to develop a particle level model of matter. Subsequent lessons in this storyline (see Online Resources) help students refine that model to account for evaporation, condensation, and infiltration into the ground. Those later lessons also help students develop important ideas about the distribution of freshwater reservoirs on Earth, the flow of water between them, and ways that people can implement solutions to protect them. The routines outlined in this paper help support students in meaningful engagement in the three dimensions of the Next Generation Science Standards by leveraging their own questions and ideas in the investigations and scientific discovery of the storyline.

This unit is freely available for download along with other elementary units at https://www.nextgenstorylines.org/elementary.

REFERENCES


ONLINE RESOURCES

An outline of the storyline (unit skeleton) https://tinyurl.com/tx2dfy5j


Blog documenting a virtual storyline https://brinzaengineering.weebly.com/cleandirty-water1/previous/3

Blog documenting an in-person storyline implementation (prior to this year) https://brinzaengineering.weebly.com/down-the-drain/previous/3

Examples of plumber camera videos: https://www.youtube.com/watch?v=9rf7_pjkEeY https://www.youtube.com/watch?v=j2e6XmTPX5E

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