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# Socioscientific Modeling: Helping Students See Systems and Understand Messy Issues

BY ERIC A. KIRK , TROY D. SADLER , ZHEN XU , JAMIE N. ELSNER , REBECCA R. LESNEFSKY , LI KE , AND LAURA ZANGORI 

## ABSTRACT

In this article, we present a strategy to help students unpack complex, socioscientific issues. We outline a 90-minute learning experience during which students are asked to explore the complicated cause-and-effect relationships that shaped the course of the COVID-19 pandemic. This approach challenges students to represent the ways scientific content such as viral transmission can shape social issues such as economic hardship and mental health. Students engage in the scientific practice of modeling and address two crosscutting concepts: [1] cause and effect and [2] systems and system models. Although this example uses COVID-19 as an anchoring phenomenon, this lesson can be adapted easily to target other content, making it a versatile tool for teachers trying to help students make sense of complex issues and understand how science impacts their daily lives.

**KEYWORDS:** Socioscientific Issues; Modeling; COVID-19; Ecosystems; Systems Thinking

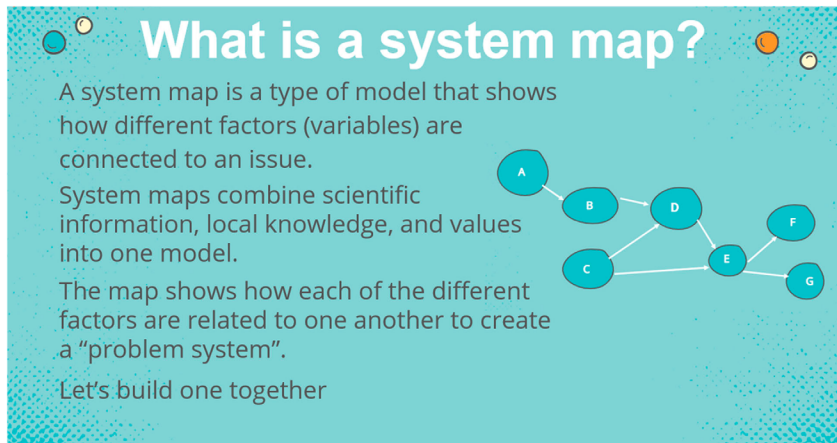
As educators, we hope to equip students with skills to make the world a better place. Many of society's biggest challenges like climate change and COVID-19 are best understood when science knowledge is applied with knowledge learned from other disciplines such as economics or ethics (Zeidler 2014). These issues, known as *socioscientific issues*, are incredibly complex and involve many people with differing experiences and interests. This makes designing solutions challenging (Sadler, Barab, and Scott 2007). If we want to prepare students to address these issues, it is important to provide them with tools that help them do so.

In this article, we describe a way of providing students with one such tool: system mapping (Figure 1). Understanding systems like those involved in socioscientific issues is often difficult for students because relationships within a system are complex, abstract, or counterintuitive (Grotzer 2012; Yoon, Goh, and Park 2018). System mapping is a modeling activity designed to help students overcome these challenges. System maps illustrate causal relationships within a system using bubbles to represent important factors and arrows showing the connections between those factors (Ke et al. 2021). These models can be used as a form of formative assessment, providing an opportunity for

students to showcase relationships between factors they have observed or inferred prior to, and during, the learning experience.

## Mapping socioscientific systems

At first glance, system maps resemble concept maps. What differs between these resources is their focus. System maps are used to unpack complicated cause-and-effect relationships. Concept maps may include cause-and-effect relationships but also feature other conceptual relationships. For example, a concept map related to water pollution could include the idea that "water quality *influences* health," which

**FIGURE 1:** Introducing system maps.

expresses a causal relationship as well as a conceptual relationship such as "nitrate runoff is a type of pollution." A system map on water pollution would only feature the first idea because the emphasis is on causal connections.

Socioscientific issues are inherently interdisciplinary (Zeidler 2014). Well-rounded understandings of socioscientific issues incorporate ideas from science as well as other areas such as economics, history, and morals (Ke et al. 2021). Because of this, system maps that represent socioscientific issues may incorporate evidence that is not typically considered when engaging in modeling. It is true that teachers have expressed concern about devoting valuable time to nonscience content (Ekborg et al. 2013), but research on argumentation has demonstrated the value of doing so (e.g., Sadler and Donnelly 2006).

While creating system maps, students engage in three-dimensional science learning as

described in the *Next Generation Science Standards* (NGSS Lead States 2013). System mapping provides context for science content through the scientific practice of modeling while emphasizing two crosscutting concepts: cause and effect, and systems and system models. Additionally, models that emphasize how science interacts with societal challenges can help students see value in technical aspects of socioscientific issues by placing them in conversation with the concrete and personal dimensions of issues that they are more likely to be interested in Kirk et al. (2023).

### Lesson sequence

This lesson is positioned as an entry point to a multi-day unit focusing on viral respiratory pandemics for a class of middle-school students ranging from sixth to eighth grade. This activity is divided into two 45-minute blocks. The first block scaffolds students' knowledge of how to create and use system maps so that they can construct models on

their own. The second day focuses on student creation and analysis of system maps. This lesson requires a way to display a slide deck, as well as writing supplies for groups to use collaboratively (e.g., whiteboards and markers, butcher paper and pencils). Although we relied on system slides for this example (see [Supplemental Materials](#)), we have had success in early iterations walking students through the activity using only a whiteboard. Teachers without access to technology may recreate the introductory worked example piece by piece using a whiteboard following the sequence presented in the PowerPoint with minimal added effort. Despite this lesson's focus on COVID-19, this approach could be adapted for other content by modifying the prompts during the second day.

### Day 1: Introducing system mapping

The first day is designed to introduce students to system mapping and the conventions of system mapping, by providing a worked example of how to create and use a system map. The lesson begins with an introduction to system maps (Figure 1). The teacher emphasizes that system maps are tools to help understand complicated problems by highlighting cause-and-effect relationships between factors that are relevant to the issue. Next, the teacher walks the class through constructing a map together, using a topic that their students likely possess prior knowledge of (water quality, in our instance) as an example.

During the worked example (Figure 2), the teacher introduces students to the conventions of system mapping. Because this lesson is designed to help students understand the ways scientific knowledge can be used to help address social issues, it is important to include factors that are best studied with scientific methods (e.g., water quality, ecosystem health) and other methods (e.g., economic impacts, justice issues). Circles represent important factors related to the issue; relationships between factors are represented using arrows running from cause to effect.

In early implementations of this lesson, we found middle school students often resorted to writing several sentences in each circle, describing the factor in detail as well as the nature of the

relationship between factors. They also did not always use arrows consistent with system mapping conventions. To address these challenges, we now introduce three rules to ensure students represent their ideas concisely:

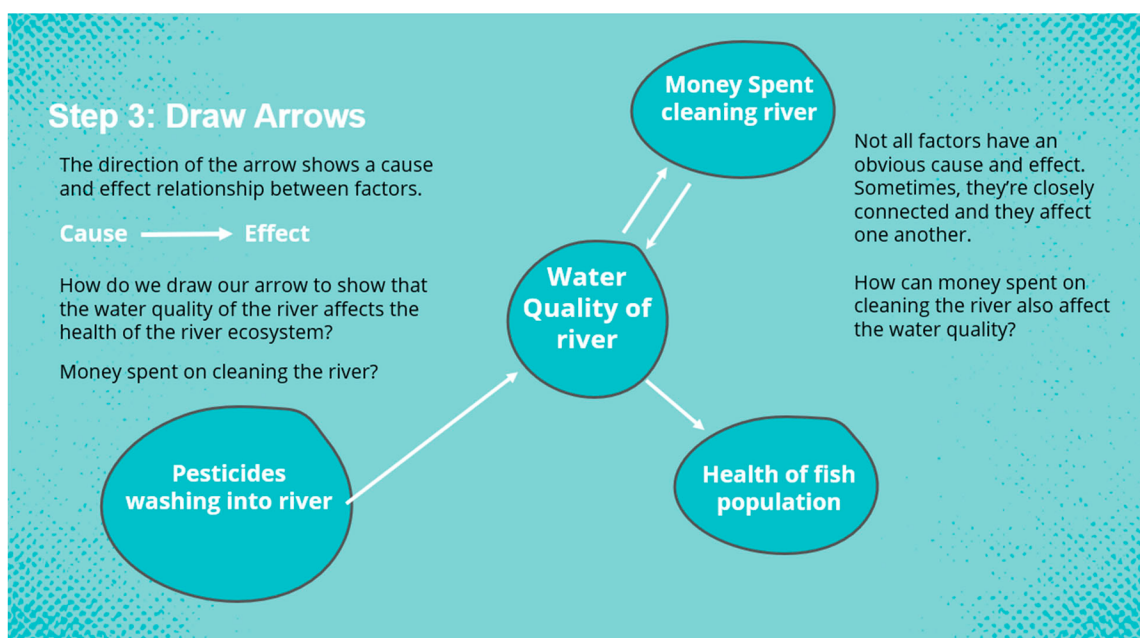
1. Factors (circles) should have no more than five words.
2. Arrows showing relationships always go from cause to effect.
3. Arrows can only go one way, but you can use more than one arrow (Figure 2).

Students easily took up these rules, and as a result, their maps communicated ideas more effectively. Depending on the needs of the class, the worked example takes between 15 and 25 minutes.

The first day of the lesson concludes with two application tasks

where students are asked to use the model as a problem-solving tool. First, students are asked to use the model to predict how limiting pesticides would impact the health of residents. Students are given a few minutes to talk with their group before sharing their ideas with the class. The teacher then walks through the causal chain connecting those two factors. The second task (Figure 3) asks students to use the model to propose and justify actions to protect the health of the eagle population. The purpose of the second task is for students to use their system maps as a tool to support their thinking and develop a solution to a problem. Some groups used their maps to do so, working backwards from “health of eagle population” step by step to identify factors that their plans

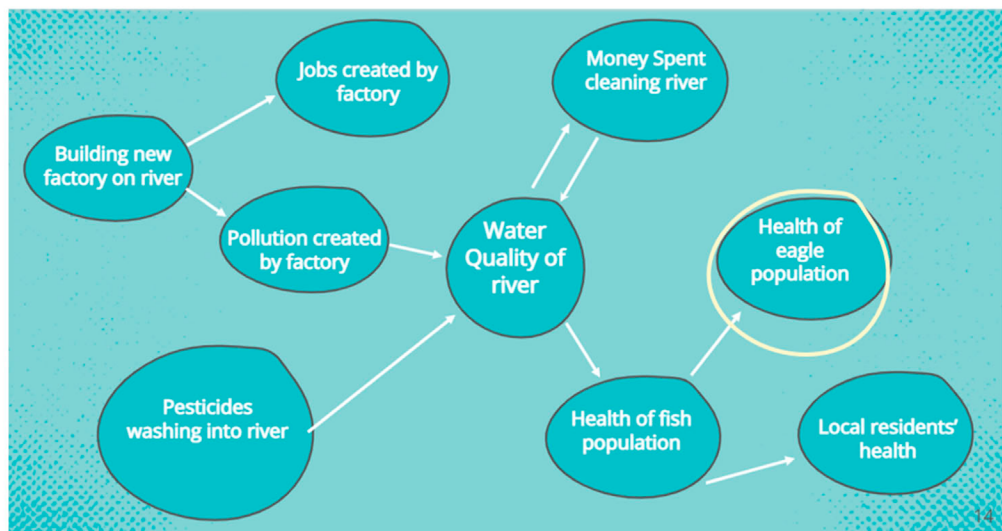
**FIGURE 2:** Using water quality as a worked example.



**FIGURE 3:** Example application task.

- 1) What actions should a town take to protect the eagle population?
- 2) Why are these actions the best actions to take?

Use this map to help inform the decisions you make!



might address to protect the eagle population; however, others did not refer to their system maps at all during the task. When asked, these students could use the map to justify their recommendations but did not necessarily use it to identify potential solutions as we had intended. Depending on a teacher's goals, this may be an opportunity to provide extra support in terms of how students can use their maps as tools to help them consider complex problems.

### Day 2: Modeling COVID-19

Day 2 begins with a review of key features of system maps (i.e., factors and relationships), the purpose of system modeling (i.e., illustrate cause and effect relationships), and potential uses (i.e., predicting outcomes and designing solutions). We then introduce the idea of creating system maps that represent their experiences and understanding of the CO-

VID-19 pandemic. In constructing their system maps, students construct models which represent causal relationships they have observed throughout their experiences during the pandemic. Students spend a few minutes working in groups to brainstorm factors that affect, or are affected by, COVID-19. Groups then share examples of items from their lists. Depending on the needs of the class, brainstorming could also be done collectively to ensure students have scientific and societal factors to draw on when they create their group maps.

Next, students are reminded of the three rules for constructing system maps. Groups begin generating their system maps by writing "Number of COVID-19 Infections" as the central factor before working together to craft the rest of their maps. Students work in groups to generate new ideas for their maps for about

10–15 minutes and then participate in a gallery walk to see ideas that their peer groups had developed. One group "spokesperson" remains with their system map, while other group members travel to different groups to learn about the factors and relationships highlighted by their peers. Following this peer review, the original groups come back together and revise their maps. The process proved to be very useful for some groups, helping them see relationships they did not initially consider, resulting in far more complex maps than before the gallery walk. The lesson concludes with groups sharing their models and reflecting on their experiences.

### Reflections

Overall, the groups were successful in representing and describing the ways scientific factors (e.g., number of infections) interacted with social issues (e.g., mental



health). Students had positive things to say about the lesson, noting that the activity was both fun and a helpful learning experience. Students also reported seeing value in the system mapping approach more broadly, identifying new content areas where they could see this type of model being helpful.

## Adaptations and differentiation

Although this lesson could fit at any point during a unit sequence, we feel it works best as an opening lesson for a unit. Constructing these models early provides students with a resource to relate more abstract content to their lived experiences and serves as a preassessment, providing teachers with insight into what knowledge students are bringing into a unit. Once students construct their initial maps, teachers may ask them to revisit and revise the maps as they continue to develop deeper understandings of the science underlying an issue or use these models to design and advocate for various solutions. These maps can help teachers identify misconceptions held by students or gaps in their understanding so they can adapt upcoming lessons accordingly. We designed this activity primarily to support student thinking and recommend against its use as a summative assessment.

During initial iterations, we asked students to label arrows with plus or minus symbols to communicate whether factors were

positively (e.g., as X increases, Y increases) or negatively (e.g., as X increases, Y decreases) correlated. We found students of all ages struggled to use these conventions consistently but could articulate factor relationships verbally, indicating they understood how factors are related to one another but were struggling to apply the labels we suggested. Asking students to use these labels slowed progress and created confusion, without helping students use their maps to unpack phenomena—our primary goal. Still, teachers may find these conventions helpful depending on their goals and willingness to devote time to additional scaffolding, particularly if they wish to challenge an advanced group of students to think about relationships in terms of correlations.

Finally, teachers may wish to consider grouping strategies based on the needs of their classroom. Although we have had success implementing these activities with individual students and pairs, we found groups of three to five students generated the most productive conversation and participation by all members. Teachers may wish to create mixed-ability groups to encourage cooperative learning, or skill-based groups for students who may benefit from more one-on-one support from an instructor (McLeskey, Rosenberg, and Westling 2013). For classrooms with a wide range of student abilities, the teacher may also wish to construct a whole-class model to ensure all students are equipped with a useful model.

## Conclusion

We present an approach to modeling to help students understand socioscientific issues by representing the complex causal relationships that make these issues so difficult to resolve. Although this approach differs from traditional scientific modeling, students still meaningfully engaged with science content, science practices, and crosscutting concepts. Students represented and described the relationship between a wide range of factors and reported enjoying the activity. Perhaps most important, students saw value in the potential for using the system-mapping approach to address problems beyond what we asked of them during the lesson. •

## SUPPLEMENTAL MATERIALS

Systems slides — <http://dx.doi.org/10.1080/08872376.2024.2314698>

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