Visual representations of the complex interactions and interdependencies within systems facilitate holistic understanding and inform decision-making for systemic improvements.

"EVERYTHING'S CONNECTED"

USING SYSTEMS MAPS FOR INQUIRY LEARNING

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Systems maps? Gretchen had never heard of them until the summer of 2019, but Laurie started investigating their use in 2017. Now we both recognize their potential for structuring inquiry learning, developing culturally responsive and sustaining classrooms, and engaging teachers and students in deep discussions about the complexity of life. In this article, we will give an overview of systems mapping, including a description of how they are different from other types of mapping strategies, discuss the benefits of systems mapping in K-12 classrooms, and provide a three-step process for introducing systems mapping in the classroom.

Systems Maps: An Overview

Systems maps can take different forms with alternate names, such as network maps,[1] part-whole diagrams,[2] and semantic networks.[3] Basically, systems maps are a type of graphic organizer to document student thinking. They often look like webs: they begin from a central topic and move outward to document the components and connections surrounding the central topic (aka system). As systems maps are organic, students do not receive pre-determined parts to arrange on a graphic organizer; instead, components are recorded as the class discusses the networks of a system. One teacher described systems maps as a "conversation on paper." Maps for the same system will look different between classrooms and across time, reflecting students' varying conceptions of what makes up a particular system and the relationships between the components. Based on students' needs, teachers can tweak the mapping process. For example, images can be added with young learners. Additionally, systems maps bring different cultural ideas to the discussion, producing pluralist outcomes not centered on the norms of educational achievement.[4]

Systems maps differ from traditional graphic organizers because they are generated by students during class discussion. They are also distinct from web organizers because the emphasis is not on organizing information, but rather on student discovery of complexities in relationships within (and between) natural and social systems with both human and non-human elements. Additionally, systems mapping emphasizes repeated revision as new learning occurs.

Three Benefits of Systems Mapping

As teachers continue to explore systems mapping as integral to inquiry, the purposes and processes become more nuanced. However, we found three primary benefits to creating systems maps: they nurture inquiry learning, they promote culturally responsive and sustaining pedagogy, and they represent holistic systems thinking.

Co-constructing Inquiry Learning

Systems maps provide structure to inquiry-based learning methods, which emphasize student

learning through investigation in a process similar to that used by professional scientists and researchers. Systems maps provide a starting point for such a method: teachers can assess what students already know about a topic, what they do not know, what they need to know, and what they are curious about. Then, after students investigate, experiment, and/or research, maps provide a canvas on which to record answers to questions and hypotheses. Using systems maps in this way helps students with content learning and problem solving.

A Culturally Responsive and Sustaining Literacy Practice

Systems maps are an asset-based method of instruction that draws on students' prior knowledge, experiences, culture, and language. Students' ideas are valued in discussion and writing, and ideas are discussed in context. Importantly, systems mapping helps students make connections between their own lives and the curriculum, which is vital to engaging students in learning. Systems mapping scaffolds multiple perspective-taking and vocabulary development, notably effective with English language learners and helping students understand their own disabilities. Familial practices can be represented in maps about foods, processes (e.g., reading the Bible), and languages. Systems mapping also positions the teacher as a learner along with the students, making a more democratic classroom. Students' ideas are saved and revisited; their developing ideas hang in the room for all to see, increasing the confidence of these growing investigators.

A Holistic Textual Representation of Systems Thinking

Systems maps are a visual representation of systems thinking, a set of skills that helps students understand life as complex networks of relationships, patterns, connectedness, and context. A system is anything with two or more related parts. For example, a school is a system: it has multiple interacting parts in a specific location. Systems thinking provides a holistic, contextual view of life that emphasizes the importance of the connections and interactions of system components when trying to learn about or improve a problem in a system — especially when solving particularly challenging problems such as the climate crisis, human trafficking, or disease.

Systems thinking is becoming more prevalent in schools, especially science classrooms, because of its inclusion in the Next Generation Science Standards for all ages.[5] Beginning in kindergarten, students are expected to track patterns across time, argue how humans and animals can change the environment to fit their needs, and compare sustainability solutions. While systems thinking is often considered a higher-order thinking skill, young children are able to do this type of thinking. Research demonstrates the potential for student learning about complexity[6] in science,[7] language arts,[8] and social systems[9] in classrooms of all ages. Using systems mapping is a pivotal classroom activity when beginning systems instruction because it provides a solid foundation for all systems thinking: the parts of the whole, the parts of the parts, and the relationships between the parts and the whole.

The mapping method we will describe here came from research we conducted during a professional development institute on systems thinking. The four-day professional development was led by experienced systems thinking teachers who described using systems maps regularly in their classrooms.

Systems Maps: How To Do It

During the institute, the teachers learned that systems mapping does not come as part of a packaged curriculum; it is a context-based product of interactive class discussions. Completing these maps as a student-teacher collaborative activity during class discussion, combining oral and written exchanges, provides the space for students "to make their ideas visible while being malleable and available for discussion, which enables students to make meaning out of systems."[10] In the following, we use one of the maps the institute participants created about a broken pencil (see Figure 1)

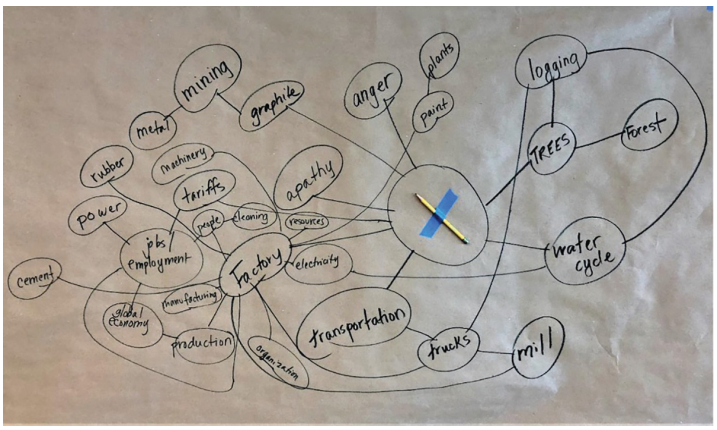


Figure 1. **The Broken Pencil Map. A systems map created by a group of teachers during a systems thinking pedagogy professional development.**

to illustrate how teachers and learners can co-produce systems maps that reflect inquiry learning, culturally sustaining practices, and systems thinking. Then we offer suggestions for beginning a first map, expanding the map, and later revising the map, all of which are important elements to implementing systems maps.

Step 1: Beginning the Map

Teachers can introduce a systems map at any point in a unit of study. There is no need for any lessons about either the topic or systems thinking prior to beginning the first map. Ideas will arise from students' prior knowledge, which makes systems maps an ideal introductory lesson to any unit of inquiry. To begin the first systems map, teachers need a large space to write, like a piece of butcher paper or a white board. Then, the teachers select an item or event familiar to them and their students. Some suggestions from the experienced teachers in this study included using a "favorite thing" for the center of the first map. For example, one 2nd-grade teacher started with a carrot because the class was going to be studying gardens and a 1st-grade teacher used the ocean because it tied into their next social studies unit. One of the institute consultants used a broken pencil as the center of the map during a whole-group activity; she had used a broken pencil as a map center in her 5th-grade classroom after finding yet another pencil fragment on the ground (something we think all teachers can relate to!).

The first goal is to get students talking about the topic. So, once the center item has been shared, the teachers pose a question to their students about the item. For example, if the teacher is using a favorite object, they might ask, "Where did [the item] come from?" Similarly, if using an activity like a

neighborhood walk, they might ask, "What did you notice while we were walking?" For the broken pencil map, the first question posed was, "What do you think created that pencil?" Below is a snippet of the discussion that followed. (Note: During the institute, the facilitator served as the group leader, asking questions to prompt the participants; a second person served as map scribe, recording the responses on a large sheet of butcher paper. In the classroom, a teacher normally would fill both roles at the same time.)

Teacher Participant (TP) 1: "Forests. Water cycle."

TP 2: "Are you talking about the broken pencil or a whole pencil?"

Group Leader (L): "We have both kinds."

TP 2: "Trees."

Map Scribe (MS): "Where do you want that to go?"

TP 2: "Over there [with forests]."

L: "Okay, so we have forests, the water cycle, and trees. What else?"

MS: "Wait, do you want the water cycle to go up here or separate?"

TP 1: "Down there. On its own."

TP 3: "What about the not-caring system? For the broken pencil?"

TP 4: "The apathy system."

MS: "Okay, where does that go?"

TP 5: "The anger system? Someone broke it?"

L: "Okay, what other systems created this pencil?"

TP 6: "Transportation?"

L: "Okay, do you want to say a little more about that?"

TP 6: "Uh, yeah, because it had to get from one place to another for, uh, consumers to buy it. For the children to have it."

MS: "What system did you say?"

TP 6: "Transportation." [Gestures to the open space on the left side for placement.]

L: "So how did they get transported?"

TP 6: "It could be by . . . trucks?"

L: "Okay, so truck. Is that a system?"

TP 7: "The truck system?"

TP 6: "Well, when I said transportation, that would include the trucking system."

MS: [Draws a line from trucks to transportation.]

L: "Okay, where did they come *from* on the trucks?" [Calls on a TP with a hand raised.]

TP 8: "Well, I was going to talk about the manufacturing system. So, after the forest and before the transportation it had to be transformed from raw materials into a product. So, um, in between the forest and trucks, I guess?" [Gestures to the map.]

L: "Okay, so you're saying the factory system? And so do the trees go straight to the factory?"

TP 9: "The logging system."

L: "Ah, the logging system. So what system is the logging system a part of?"

The example shows how, from one question, the conversation expanded quickly into many topics. As teachers responded, the scribe wrote down the responses and used lines to connect them appropriately. The broken pencil system map included factories, transportation, trees, and water as the main responses about the system, so those were connected to the broken pencil in the center. As students respond with ideas, the teacher's primary role is to record the ideas on the map, branching out to include the suggestions from learners about what is "connected to" and "a part of" the central system.

Recording students' ideas on the map can be done in various ways. One option is to ask students where they would like their suggestions to be placed on the map. This helps communicate to the students that the map is "theirs," locating student thinking at the center of the classroom — an idea central to culturally sustaining pedagogies. A second option is to spend the first mapping session having learners "just throwing out ideas," then return later to let the students revise the map's organization. The important thing is for teachers to know that either option works. While the process might feel foreign at first, it will become more natural with practice.

Step 2: Using Follow-Up Questions to Extend Class Thinking

While recording students' ideas, the teacher's other role is to act as a questioner. Asking open-ended questions is critical for developing systems maps. The discussion might seem unfocused at first because it is more reliant on students' thinking than most traditional instruction; however, the teacher is guiding the discussion with questions. The goal is to prompt students to think of as many system components as they can; this way, students begin developing their understanding of connections within systems as they explore their prior knowledge about the topic, "enriching strengths rather than replacing deficits."[11] To guide the conversation about the broken pencil system, the map leader/teacher asked questions like, "What else?," "Where does that go?," "Can you say more?," and "What other systems are a part of that?" It is important that the questions remain open-ended, so students do the thinking, and that risk-taking is encouraged.

Once students have identified some of the main components of the system, the teacher's questions can expand the map to topics that students had not brought up themselves and/or narrow the map by asking more detailed questions about the components already mentioned. This type of mapping goes beyond typical narrow priorities of boxed curricula to draw on students' already-developed prior knowledge, deepen students' understandings of the system, and find areas for inquiry. Open-ended questions provide prompting and support for students to make distinctions between systems components, identify influences on a system, and develop suggestions about the system. By asking questions, the instructor can scaffold the discussion so learners can progress in their understandings about relationships between components as well as the relationships between wholes and parts. Wait time is critical. Taking time to think together shows students they are a part of the classroom community and builds the relationship between the teacher and students.

Questions asked during the broken pencil map included what people and natural elements were connected to the pencil; what the connection(s) between two components, like trees and transportation, might be; and what pencil factories entailed. The teachers agreed that learning to ask open-ended, strategic questions was challenging at first, but also agreed it was valuable. As one teacher stated, "Telling isn't teaching. Teaching is about thinking." They found that having a list of question stems was helpful, and Figure 2 lists the open-ended question stems that the teachers produced during their practice.

WHAT...		WHO/WHERE...	HOW...
What are the systems in this?	What other connections does that have?	Who is a part of this?	How did/does that happen?
What happens next?	What else could you say about that?	Who would be there?	How do those things connect?
What do we call that?	What happens in between those parts?	Who would that affect?	How are those things similar/different?
What does this need?	What other parts does that have?	Where does that come from?	How could that interrupt another system?
What would that affect?	What problems are in this system?	Who makes that decision?	How should that be mapped?
What comes into play with that problem?	What systems in our country does this connect to?	Where does that connect?	How would that happen?
What is the source of that?	What is something bigger/ smaller than that?	Where does that go on the map?	How could this make an impact?

Figure 2. Question Stems. A chart of question stems is useful when first trying a systems map in the classroom. This chart was created from successful questions that participants of the professional development used while they practiced leading systems maps.

Systems mapping in this manner takes some time to complete. Teachers often plan at least 30 minutes for the first session. One teacher explained that she initially thought mapping was aimless and time-consuming; however, after watching her students become engaged, she decided to try it and found that it "transformed" her pedagogy into an inquiry-based style.

Step 3: Revising the Map

Systems maps are not created and tucked away in a closet as a "finished" product. They document the students' thinking at a certain point in time, and they provide a record of original thinking that can — and should — be revised. Revisions to the map come as students continue to learn more about the system through inquiry and activities, such as classroom lessons, readings, experiments, or field trips. It is more than "okay to return to maps over and over" because "understanding . . . deepens as we revisit them." One teacher explained that "it's important to sign-post back" to the maps after learning activities, asking what needs to be changed. The students work together to recursively revise the map. Using new learning as feedback for recursive revisions "strengthens neural pathways"[12] Adding to, removing from, and adjusting maps showcases how the students' thinking has changed. They also begin to develop key understandings about other systems principles, such as learning is recursive, inquiry is continual, and "everything's connected."

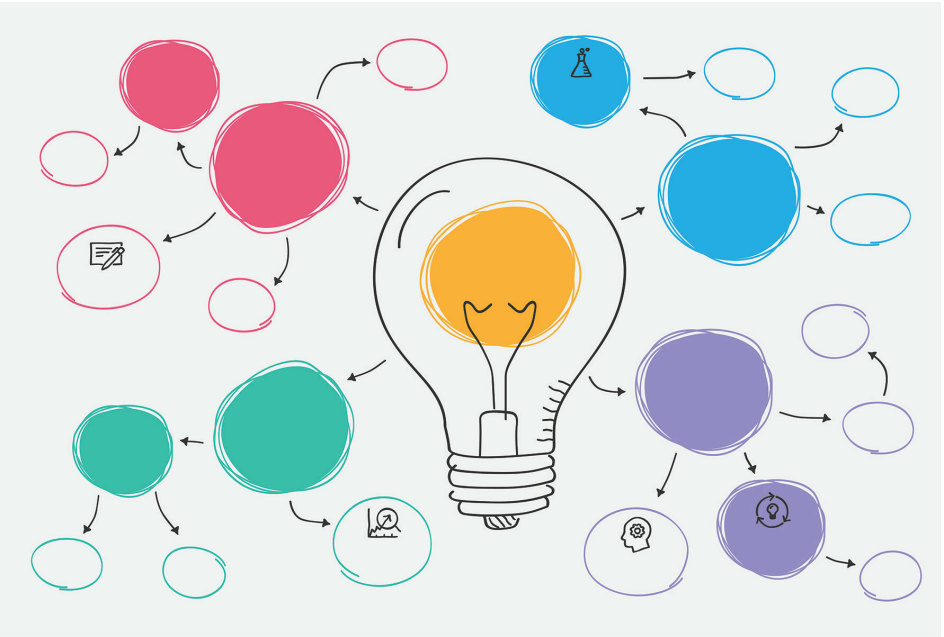
Mapping provides an entry point for improving teacher and student understandings of inquiry and systems thinking.

For example, when making the broken pencils systems map, the discussion stopped when the map leader prompted, "Tell me more about logging." One participant admitted she did not know much about it, and others agreed. In the classroom, this would be a possible direction for future lessons. Thus, the process of

mapping identifies points of interest for additional learning. For example, the teachers in the institute spent a lot of time discussing factories, wages, and the global economy as they completed the broken pencil map. In the classroom, teachers can take these opportunities to use students' natural interests to engage them in learning. As is inevitable in true inquiry, mapping will lead to questions that teachers do not have answers for; this provides an opportunity to research and learn together while humanizing the teacher and personalizing the curriculum. Additionally, the process of recursively revisiting maps provides a natural way to return to further inquiry; makes the environment more enriching, especially for English language learners; and provides scaffolding for students as they connect new learning to their established cultural schema.

Conclusion

Mapping provides an entry point for improving teacher and student understandings of inquiry and systems thinking. While systems mapping was challenging for the teachers in the beginning, with practice they described it as "inspiring" and, due to its asset-based foundation, even "life-changing." Systems mapping can be done at any age and for any subject. The institute participants gave examples of the water system for 1st-graders, the immigration system for 3rd-graders, and the systems in a novel for 4th-graders. While the task of integrating systems thinking, inquiry learning, and culturally sustaining practices into one's practice may feel daunting, mapping is an easy entry point to all three that can have a great impact on student thinking.



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