Designing Text-Based Investigations for Evidence-Based Argumentation in Science

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Project READI Technical Report #17

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Project READI operated as a multi-institution collaboration among the Learning Sciences Research Institute, University of Illinois at Chicago; Northern Illinois University; Northwestern University; WestEd's Strategic Literacy Initiative; and Inquirium, LLC. Project READI developed and researched interventions in collaboration with classroom teachers that were designed to improve reading comprehension through argumentation from multiple sources in literature, history, and the sciences appropriate for adolescent learners. Curriculum materials in the READI modules were developed based on enacted instruction and are intended as case examples of the READI approach to deep and meaningful disciplinary literacy and learning.

I. Introduction

In the first year of the project, members of the Project READI science design team conducted a conceptual review of the literature on the nature and epistemology of science, the demands of literacy in science, and many empirical studies of science education to describe the kind of knowledge required of science readers if they were to make evidence-based *scientific* arguments from multiple sources. The collaborative Design Team conducting this review included curriculum and instruction designers; literacy, learning sciences, and cognitive researchers; a research chemist turned teacher; and high school and middle school science teachers with expertise in different branches of science. The team also consulted the Common Core State Standards (particularly standards 1, 7, 8, and 9), the College Readiness Standards, relevant state standards (e.g., California's Science Standards), and the 1996 and 2010 draft versions of the National Science Education Standards to inform our conceptualization of the core constructs for evidence-based argumentation from multiple sources (AAAS, 1993; CCSSO, 2010; NRC, 1996, 2010).

We also referenced the literacy, science education, and learning progressions literature for guidance on various dimensions of the core constructs (e.g., discourse, genre, and working with multiple representations) (e.g., Berland & McNeill, 2009; Cavagnetto, 2010; Corcoran, Mosher & Rogat, 2009; Gotwalls, Songer & Bullard, 2009; Lehrer, 2009; Radinsky, Oliva & Alamar, 2010). We further defined the scope of these constructs to be limited to reading rather than to hands on investigations requiring students to design investigations, learn to wield various science equipment and conduct accurate measurement to collect and analyze data. In other words, the core constructs of interest in the context of the READI project are those important to what Palincsar and colleagues have called second-hand inquiry (Palincsar & Magnusson, 2001).

Our rationale for this decision was the following: Students in reform science classroom are currently engaged in such hands-on investigatory activities but they are not involved in investigations that centrally involve the use of authentic science texts to construct knowledge, draw on information and evidence, and develop explanations and arguments that bit fit the data. Science, however, requires such knowledge and skill (Yore, Bisanz & Hand, 2003; Yore, 2004; Osborne, 2001). Many modern scientists work with extant data sets, such as huge databases on global climate measurements made over centuries, ice core sampling, and similar types of data that they themselves did not collect. To learn to practice science, students need to build the literacies required in such an enterprise, and we reasoned that supporting students to develop science-specific literacy is where the READI grant might offer new value to the field. At the same time, as we develop instructional modules, we plan to explore ways to integrate or coordinate them with hands

on inquiry activities that are currently in place in existing science curricula. Our teacher collaborators will be especially important to our efforts to do this.

The science design team engaged in an extended iterative process of proposing and revising the functional definitions and illustrations of core constructs of knowledge underlying science literacy practices, with different subgroups consulting literature on development of key science principles, rhetorical analyses of science texts (e.g., Goldman & Bisanz, 2002; Kerlin, McDonald & Kelly, 2010; Lemke, 1998, 2004; Waldrip, Prain & Carolan, 2006; Yore, Bisanz & Hand, 2003), and research on the public understanding of science, the role of diagrams, models, and simulations in science learning (e.g., Schwarz, et al., 2009; Stieff , 2007; Stieff, Hegarty & Deslongchamps, 2011; Sanchez & Wiley, 2006). We then worked to identify performance benchmarks for 12th grade students to demonstrate the knowledge required to make evidence-based arguments from multiple text sources in science, which led to further revisions in the core constructs. Emergent from our reviews of this literature was a defining focus for our work: reading for understanding in science, particularly reading to carry out argumentation in science, centered on developing explanations and models of science phenomena and arguing from evidence to support them. Further, we recognized the multi-modality of science representations and the necessity of supporting students to learn to make meaning of these semiotic systems. The resulting core constructs and benchmarks for 12th grade are attached.

Having summarized the literature to develop core constructs to guide our work, the READI science design team worked across sites and with teacher design partners to develop and field test two intervention units during first and second year of the project. Module 1 of the READI Science Units, on Methicillin-Resistant Staphylococcus Aureus, or MRSA, is currently being implemented in high school classrooms. A second module is currently being finalized on the topic of human impacts on water purity. It will be implemented in middle school classrooms in the spring. Both modules share a common architecture based on the 14 shared design principles developed by the larger Project READI team and address the project-developed core constructs of knowledge for science, plus one additional design principle drawn from Lee (1995) on cultural modeling.

Both modules were developed with extensive input from the science teachers in the California Teacher Inquiry Network, who supported topic selection; text identification and sequencing; assisted in task development; and enacted close reading and tasks embedded in the modules to develop and refine pedagogical approaches and scaffolds. The work of the California Teacher Inquiry Network was conceptualized as ongoing design partnership and design research around the shared problem of teaching scientific argumentation from multiple sources. Science teachers assisted in developing materials and approaches for students, and at the same time, our inquiries with them were designed to develop and field test professional development experiences to be used across the project as the work moves

forward (see READI Tech Report #24; Greenleaf & Schoenbach, 2004; Greenleaf, et al., 2011 for a description of the inquiry-based professional development approach taken here). In addition, individual science teachers in each site volunteered to implement the modules and work as design partners to reflect on their implementation and support further refinement of the modules. The iterative implementations and resulting refinements of the modules will be reported in subsequent technical reports. In the remainder of this report, we delineate the theory and rationale underlying the design of Text-Based Investigations in science that build on and instantiate these core constructs. We illustrate throughout with examples from the MRSA and water modules.

II. Theoretical Rationale and Principles for Designing Text-Based Investigations

Reading for understanding in science requires that students build a robust internal model of science phenomena from evidence and ideas in source materials. Both units, the MRSA and the water unit, aim to place sense-making with texts in the hands of students to see to what extent the model of instruction and architecture of the unit support students in learning the science from their intellectual work with these sources, rather than from lecture, demonstrations, or textbooks that are designed "deliver content" to students (Alozie, Moje & Krajcik, 2010; McNeill, 2009; Norris & Phillips, 2003). We hypothesize that due the nature of science textbooks (compendia of well-established science facts and theories) and the way the goal of science instruction is often framed (as knowing correct answers to questions the teacher poses), students will be socialized to scanning science texts for information rather than to engaging intellectually with texts to construct deep understanding or to using texts as sources for inquiry (Evagorou & Avraamidou, 2011; Berland & Hammer, 2012). An explicit goal of the unit, then, is to re-socialize students to actively construct meaning with science texts and to reposition science texts as resources for inquiry (Pearson, Moje, & Greenleaf, 2010).

Toward these ends, each unit offers abundant social and material support for active sense-making and a focus on explanation/model building (NRC, 2012). While unit materials are designed to be both compelling and supportive of the active sense-making goals of the project, we know both teachers and students will benefit from the strong social and pedagogical supports for such active intellectual engagement that were built into the units (described below). Students' work with the unit materials has been designed to mirror the work of scientists – as text-based inquiry. Pedagogical routines therefore focus students on asking questions, identifying and accumulating data to answer inquiry questions, developing explanations and models, and critiquing how well their models hold up – the practices of science – rather than solely on acquiring specified content. At the same time, unit materials focus on important crosscutting concepts (cause and effect, mechanism and explanation,

systems and interactions) and core ideas central to life and Earth science domains (structures and processes, interactions, variation of traits, biological evolution, matter and energy). By using the literacy practices of science to inquire into real world topics of interest, we hypothesize that students will simultaneously learn about the content as well as literacy practices of science.

Topic Selection

To identify topics for potential module development, we undertook an extensive review of the California state science standards, science curriculum standards for Chicago Public Schools, and the emerging NRC standards for science learning. Our goal was to select topics of study that fit well within the purview of the curriculum topics teachers were responsible for teaching in different domains and grade levels.

The topic of *Methicillin-Resistant Staphylococcus Aureus (MRSA)* fits well with secondary life science courses and serves both content standards and literacy learning goals. The topic of evolution is a central organizing theory of biology and research (NRC, 2012). An important additional criterion for topic selection was the potential appeal of chosen topics for study by secondary students. MRSA was chosen as a case study of evolution because it is a contemporary example of how the theory of evolution is used by scientists today to investigate and critical solve problems that impact everyday people in typical communities around the country. In addition, MRSA disproportionately affects teenage populations.

Similarly, the topic of water resources, specifically the availability of fresh water supplies for growing human populations, fits well in the Earth science curriculum taught in middle school. Water involves interactions of matter and energy, interactions between humans and the environment, and these are central unifying concepts in science (NRC, 2012). The topic crosses domains of physics, ecology, Earth, and environmental science and thus affords the team the possibility of building on unit materials beyond the initial module to address standards at different grade levels when these various domains are taught. And because virtually every community in the US is impacted by water development, purity, scarcity, and need, there are many opportunities to localize the study of water in order to build relevance for students.

The chosen topics allow for units of study with several design characteristics that are important for unit design:

- Consist of a manageable problem space—the unit engages students in a full instructional cycle
- Afford students opportunity to read and write arguments that are personally relevant

- Draw on manageable amounts of empirical data

Additionally, because both evolution and MRSA as well as water purity and scarcity are extensively written about for both lay populations and professional scientists, extensive textual resources with a wide range of accessibility and challenge exist, making it possible to create text sets which provide plentiful opportunities for close reading of authoritative sources at various reading levels across multiple representations representative of the discipline of science.

Text Selection

Complexity. For the high school intervention (MRSA), we wanted texts to present students with the range of comprehension problems typical of science reading in school and public contexts (CCSS, Appendix A, 2010). A focus for the unit, then, is learning to grapple with the language and syntax of science as well as the multiple forms of representation typical of science writing. We wanted students to read trustworthy sources that we knew would nonetheless present ambiguities and difficulties for comprehending the science because communication through natural language is riddled with imperfection, imprecision and ambiguity. Thus we chose sources from trustworthy portals such as government and university web sites, NSF-sponsored research sites, and the like. We also chose to use science reporting from newspapers and non-print media for a variety of compelling "cases" of MRSA infection and spread which presented data as well as the science of MRSA evolution and transmission. To reduce complexity, we used selected parts of texts rather than altered texts.

Similarly, for the water unit in middle school, we excerpted text book sections and found many supplementary texts that would afford opportunities to read closely for the purpose of deep understanding and argumentation, rather than rely on traditional informational texts used primarily to supply content (Cervett & Barber, 2009). For the middle school intervention (water), we excerpted source texts heavily and altered some syntax to reduce complexity. For example, we reduced the number of unclear pronoun referents and nominalizations, though left some intact to provide instructional opportunities to tackle these normative forms of science discourse (Fang & Schleppegrell, 2010) later in the unit. More of the complexity was handled by scaffolding text sets by sequencing them in order of complexity and interest. More accessible and potentially engaging texts (photos of polluted streams with captions) were presented before more extended discourse as well as more complicated visual displays.

Multiple Representations. For these units, texts were intentionally chosen to present students with the representations typical of science – line and bar graphs, visual models, diagrams, and exposition (Fang & Schleppegrell; Goldman & Bisanz, 2002; Lee & Spratley, 2010; van den Broek, 2010). We also intentionally chose videos from the internet, public service announcements used by various agencies, and science reporting – all analyzed for their reliability on the science concepts targeted. For this first iteration of science interventions, we did not want to present students with inaccurate or unscientific texts for the reasons given above. However, since these forms of texts are characteristic of the digital information environment, students will need to be able to read these texts critically (Leu, et al. 2008). In the modules, students are supported to engage in active and collaborative sensemaking with these varied representations, learning to approach all science texts with the goal of constructing their own understanding of them. They practice transforming information from one representation into another, from words to graphs and models and from graphs and models to words, building their conceptual understanding and flexibility with textual forms in science.

For each of the modules developed, we carried out an analysis of the features and demands of each potential text, with attention to its content, affordances re: multiple representations, language and knowledge demands, and potential interest for the middle or high school students. Table 1. below shows the analysis carried out for one of the water texts.

Table 1. Analysis of Potential Text for Water Module

Text Reviewed	Connection to the Causal Model	Readability (quantitative measures)	Readability (qualitative measures)	Content (e.g., pollution, waste, use)	Multiple representations	Use with Middle School? And Requirements for Other Texts that are Needed
1. National Geographic http://environment.nationalgeographic.com/environment/freshwater/embedded-water/	Section B Water Resources & Ecology (B3)	Short phrases, intra-textual, potentially intertextual connections required, numerical data, measurement systems, comparison, scale	If the amount of water reported does not include the amounts for irrigation and drinking and processing, what does it actually represent? This could be potentially confusing to readers.	Water Use	Simple diagram of the object discussed and a short blurb of text about the amount of water it takes to produce it	Potentially – Look for a text that is clearer about what the water usage number represents or use without the extra commentary that's given under the volume of water.
Instructional implications, ideas: Using just the diagram and the numerical data across a short sample of more relevant examples (E.g.: beef, bread, cotton) provides an opportunity to collect and manipulate data into a new form that allows comparison. The water footprint calculator http://www.waterfootprint.org/?page=cal/WaterFootprintCalculator Could be an extension activity in the computer lab if we want to pursue the goal of assessing water use and making recommendations about how one might change consumption habits to reduce water use. Potentially a strong critical scientific reading task. To address the qualitative issues above, instructional scaffolds for noticing confusions about what water is used for, differences in quantity/item and amount/item used/family (1 cow: 1 chicken) etc, plus scaffolds for learning how to clarify. This is a high leverage area of work, because these kinds of confusions/ questions come up all the time in science, resolving them essential to collecting, analyzing and representing data.						

Academic Language Development

All science texts present students with opportunities to learn robust word- and concept-learning strategies. Texts for the unit were chosen carefully to afford particular word learning opportunities. The unit focuses attention on the important role of words and intentional word learning in science. Students are engaged in developing word learning strategies (Nagy, Berninger & Abbott, 2006). The polysemic nature of English requires that students, as proficient science readers, become metacognitive, noticing and learning how to contextually redefine words and terms in science to more closely represent new scientific conceptions. Students will engage in routine reflection on how words they meet in everyday contexts are used in particular ways in science.

Reading for Conceptual Change

Scientists read science expecting that their understanding may change as a result of compelling new evidence. We hold the goal that students, as science readers, will come to expect that their conceptions, too, may be challenged by new evidence and will learn to deliberate the strength of evidence and whether that evidence implies that they develop new understandings of the phenomena. The MRSA unit includes repeated routines for monitoring and tracking conceptual change as a model of science epistemology (Roth, 1991). Students metacognitively monitor their changing conceptions as they encounter key concepts repeatedly throughout the unit, accompanied by new evidence and information. In a manner parallel to the use refutational texts, monitoring conceptual change over the course of the unit is designed to build more robust understandings of complex concepts (Sinatra & Broughton, 2011). This metacognitive focus on conceptual change is hypothesized to result in robust concept attainment as well as new epistemological stances on the part of students. The focus on reading for conceptual change is much more implicit in the water unit, to reduce the cognitive load for students in the middle school grades.

Discourse and Argumentation

In the modules developed to date, we are tackling the goal of helping students learn to identify and use evidence from texts of varied genres and representations to learn science and make scientific arguments (NRC, 2012; Berland & Reiser, 2009). Students are frequently asked to respond to non-scientific arguments about topics (such as climate change) that bridge science and the public interest. We are convinced that developing robust models of the science through explanation and modeling of the kind we support in these modules will be a necessary precondition to success with such policy-facing tasks (see Aufschnaiter, et al., 2008). Because scientific arguments are about “best explanations of a

phenomenon given the evidence," our modules focus students on constructing and critiquing explanations, for example, for the emergence and rapid transmission of MRSA or for the impact of humans on water. In these units, students will engage in peer review processes to critique models and explanations – their own and those of their classmates (See "Peer Review" and "Science Seminars, below). Evidence/Interpretation notetakers are used throughout the units to support students in identifying and making sense of the evidence they will need to make and support their scientific arguments (McNeill & Krajcik, 2011).

Further, instruction in the units is intentionally designed to foster interactive argumentation to clarify meaning with the texts students encounter (Chinn & Anderson, 1998), as well as to establish a culture of argumentation in the classroom (Driver, Newton & Osborne, 2009). The focus on ongoing inquiry and sense-making as a mode of learning in the unit constitutes an immersion rather than formalist approach to argumentation (Cavagnetto, 2010). We take a sociocultural perspective viewing literacy and argumentation as social practices situated in and mediated by settings, tasks, purposes, and other social and linguistic factors (Newell, et al., 2011). The modules are designed to help students "argue to learn" as well as "learn to argue," acquiring argumentation knowledge and strategies through participation in argumentative dialogue with teachers and classmates.

III. Iterative Module Design Research Process

Below we detail the process of development of the MRSA module. The water unit benefitted from the MRSA unit development that proceeded it, in which pedagogical support structures were designed into the first iterations of materials for intervention modules. Thus, the design elements that were built into the module materials for MRSA informed the scaffolds and supports for the water module. This research design process, while labored and lengthy in the first module developed (MRSA), was rapidly reproduced in the second, water unit, which took less than one quarter of the time to develop.

Building a Library of MRSA Texts and a Preliminary Text Set

During July and August 2011, science Teacher Inquiry Network and READI science design team members conducted internet searches and uncovered several dozen potential texts and text sources for MRSA including news articles, journals reports, popular science magazine articles, health organizations public service announcements, educational resources, among others. These texts informed the further specification of the MRSA topic and from these texts 20 texts were selected as the preliminary text set. Texts, and

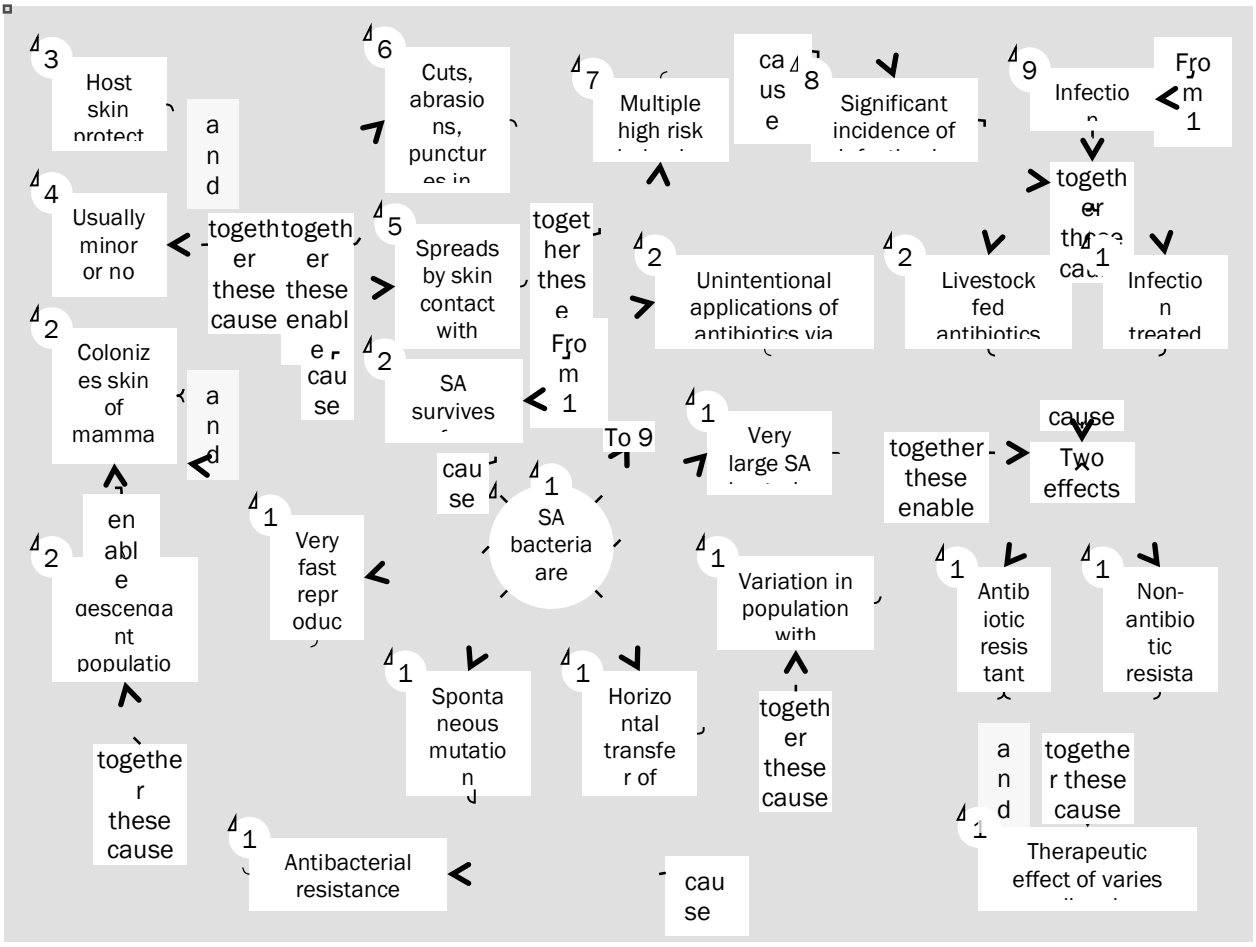
combinations of texts, were deliberately selected to accomplish multiple purposes, for example, to:

- Support development of scientific epistemology by evoking students' interests and purposes for studying the topic
- Scaffold the literacy-learning experience by positioning the most accessible, engaging texts during the initial days of the inquiry and then steadily increasing the demands and complexity of texts as time progresses
- Build schema about important scientific concepts, such as evolution, interaction and scale, as well as relevant core sub-topics such as selection and adaptation, host-parasite relationships, MRSA bacteria with high-quality, vetted informational sources
- Provide opportunities for literacy instruction and build text schema about a wide-range of science texts representative of the discipline, such as graphs, tables, current events articles, textbook exposition, public service announcements and research reports
- Develop fluency, language-learning strategies and scientific vocabulary by providing opportunities to encounter and re-encounter science-specific words and terms (including words with multiple meanings as well as qualifiers and quantifiers) the meaning of which could be derived from context
- Present models of refutational texts as a support for instruction in scientific argumentation.

Developing a Causal Model and Mapping the Preliminary Text Set to the Causal Model

During August 2011, READI science design team members developed a casual model for the evolution and spread of MRSA, drawing upon the library of MRSA texts to inform its design. Mapping the preliminary text set to the casual model uncovered a gap in the causal model and in the text set. This spurred the expansion of the casual model and texts sets to include more about the ecology of MRSA. (see figure 1, below.)

Figure 1. MRSA Causal Model



Teacher Analysis of Preliminary Text Set

In September, science teachers in the California Teacher Inquiry Network analyzed the preliminary text set. The teachers identified three cohesive subtopics within the larger topic: vector, evolution and prevention. They proposed refinement of three texts sets composed from texts within the preliminary text set for these sub-topics. The teachers also provided potential instructional sequences for these smaller sets of texts, in each sub-topic identifying accessible, engaging texts for use introducing the sub-topics and mentoring science literacy skills. Teachers also offered criticism of particular texts and specifications for alternative texts that may serve unit purposes better. For instance, teachers identified that the MRSA chronology included many science-specific acronyms and terms not explained within the document. They wanted to include a chronology but without the burden of unexplained science terms and acronyms.

Further Specification of Core Constructs for MRSA EBAIMS Intervention Unit

The Core Constructs developed by the READI science design team during the fall and winter of 2010 informed aspects of text selection throughout the design process. For example, the team attended to a variety of text types and the affordances of each text to support a developing science epistemology and inquiry practice throughout the design process. During September, members of the science intervention team further specified a sub-set of science core constructs for the intervention unit based on analysis of the preliminary text set and was able to verify that the unit provides plentiful opportunity for students to:

- Practice elements of Science Epistemology, Inquiry, and the Discourse structure of scientific arguments as they construct scientific models, argue about the validity of models based on empirical evidence and parsimony and logical coherence, thereby affording students' opportunities to explore evolution, interaction, equilibrium, and scale which are elements of Overarching Frameworks

- Develop technical and specialized science language and learn to read expressions, quantifiers, and qualifiers which are elements of science Discourse

- Develop knowledge and experience working with multiple science Text structures (cause/effect/correlation, proposition/support, description/definition, problem/solution/findings) and representations (texts, graphs, diagrams, and photographs).

Designing Unit Materials and Tools

Through iterative design stages, the READI science design team drafted inquiry questions for the unit, notetakers to support students in identifying and reasoning about evidence they encountered in the texts, modeling and explanation tasks, and culminating projects. Teachers in the Inquiry Network used and critiqued unit materials and tools to refine both their substance and the logistics of their use.

READI Design Elements Addressed in First Iterations of Text-Based Investigations in Science

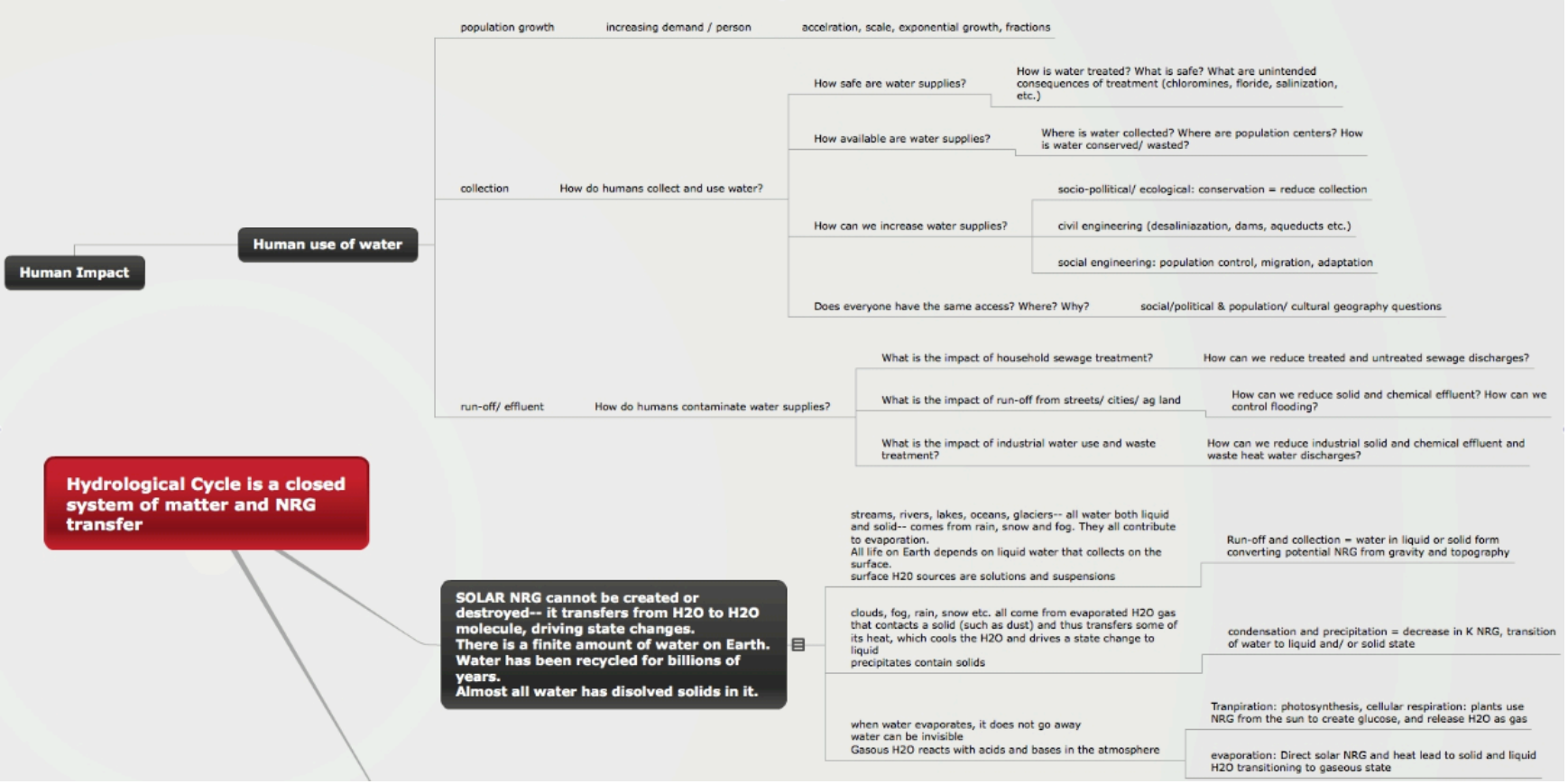
In addition to the Core Constructs, Module designs were informed by fourteen design principles that were described in the project proposal and further refined across the disciplinary teams in year 2 of the project. In the following pages, we describe how the two intervention modules were designed to address each of these Common Design Elements for READI Interventions.

1. Draw on Core Constructs

MRSA	Water
Epistemology: students experience and track their own changing understandings as a model of knowledge development from evidence (the nature of science); construct and justify models and explanations (argumentation) to advance understanding Frameworks: cause/effect, evolution, scale, interaction Inquiry processes: explanation and model building, monitoring conceptual change Representations: science news, graphs, timelines, diagrams, photographs; cause/effect models, chronology, scale models Discourse: constructing and critiquing explanations as a mode of argumentation in science; culminating task to write refutational text about how and why to prevent MRSA in their community (argument)	Epistemology: students engage with the water cycle as a model of how water interacts with other forms of matter and energy on Earth. As a model, it is an approximation with limitations. Understanding of the water cycle and human impact is influenced by—and in turn influences—cultural norms. Scientific findings have practical implications for society. (Understanding water use and disposal helps us manage this critical resource.) Frameworks: equilibrium. matter and energy, Interaction, models and explanations, evidence and representations Inquiry processes: as in MRSA, students approach science reading as investigation; construct models of phenomena based on the textual evidence; advance evidence-based claims and challenge those claims on the basis of completeness, coherence and parsimony Representations: water cycle diagrams, water utility maps, data tables, graphs and statistics related to water availability and quality, photographs, videos, exposition Discourse: as in MRSA, students construct and critique explanations. Similarly, students create a culminating argument using the knowledge about water they have gained through the unit.

2. Document Sets built around causal model

MRSA	Water
The texts actually led the development here. Having selected a "hot topic" in science, we went to authoritative sources to read about the emergence and transmission of MRSA strains of bacteria and develop our understanding of the science. We conducted searches of reliable websites to find student-friendly textual resources on the topic. We supplemented these with science reporting in newspapers and non-print media on the topic. Iteratively as we read scientific articles and reporting about MRSA, we built a causal model for MRSA emergence and spread. We selected texts from those students could handle to "cover" the necessary aspects of the model, while at the same time knowing the range of texts would raise questions and conundra for students, as well as provide needed evidence and information. We discovered the need to deal with human/bacterial ecology as well as to find/offer a petrie dish experiment to add to the text set as we developed the causal model. Thus the causal model was informed by our reading and text search and in turn informed our search for particular missing pieces.	In developing the causal model for Water, we gained an important insight—that is, attempting to describe the relevant domains of science knowledge caused us to raise questions, which we researched to clarify our own understandings of the science. From this behind the scenes groundwork, we finally were able to develop realistic and concrete learning goals. This is a difficult but essential part of the design work. As we developed the causal model, we referenced 6th grade content standards in California and Illinois. Once we had mapped much of the domain, we decided which aspects to focus on and which to eliminate. Initially, we had planned to cover the water cycle from the perspectives of earth science and thermodynamics, which are relevant content standards for this grade band. After mapping more of the domain, it was clear that human impact on water was a more productive entry point than hydrology or thermodynamics. The perspective of human impact and resource management are additional relevant content stands that allow us to accomplish two things. First, we were able to scaffold learning about the water cycle by placing easier, more engaging texts in the beginning of the unit, where we could simultaneously spend time building the complex and cognitively demanding pedagogical routines that proved difficult for teachers to enact in the MRSA unit. In addition, human impact as a topic offers more opportunity to construct inquiry-based learning experiences than are afforded by learning and reciting the well-understood water cycle.


Human Impact
Human use of water
population growth
increasing demand / person
acceleration, scale, exponential growth, fractions
collection
How do humans collect and use water?
How safe are water supplies?
How is water treated? What is safe? What are unintended consequences of treatment (chloromines, floride, salinization, etc.)
How available are water supplies?
Where is water collected? Where are population centers? How is water conserved/ wasted?
socio-political/ ecological: conservation = reduce collection
How can we increase water supplies?
civil engineering (desaliniazation, dams, aqueducts etc.)
social engineering: population control, migration, adaptation
Does everyone have the same access? Where? Why?
social/political & population/ cultural geography questions
run-off/ effluent
How do humans contaminate water supplies?
What is the impact of household sewage treatment?
How can we reduce treated and untreated sewage discharges?
What is the impact of run-off from streets/ cities/ ag land
How can we reduce solid and chemical effluent? How can we control flooding?
What is the impact of industrial water use and waste treatment?
How can we reduce industrial solid and chemical effluent and waste heat water discharges?
Hydrological Cycle is a closed system of matter and NRG transfer
SOLAR NRG cannot be created or destroyed-- it transfers from H2O to H2O molecule, driving state changes.
There is a finite amount of water on Earth.
Water has been recycled for billions of years.
Almost all water has disolved solids in it.
streams, rivers, lakes, oceans, glaciers-- all water both liquid and solid-- comes from rain, snow and fog. They all contribute to evaporation.
All life on Earth depends on liquid water that collects on the surface.
surface H20 sources are solutions and suspensions
Run-off and collection = water in liquid or solid form converting potential NRG from gravity and topography
clouds, fog, rain, snow etc. all come from evaporated H2O gas that contacts a solid (such as dust) and thus transfers some of its heat, which cools the H2O and drives a state change to liquid
precipitates contain solids
condensation and precipitation = decrease in K NRG, transition of water to liquid and/ or solid state
when water evaporates, it does not go away
water can be invisible
Gasous H2O reacts with acids and bases in the atmosphere
Tranpiration: photosynthesis, cellular respiration: plants use NRG from the sun to create glucose, and release H2O as gas
evaporation: Direct solar NRG and heat lead to solid and liquid H2O transitioning to gaseous state

3. Integrating across multiple sources is necessary for completing and addressing the task

MRSA	Water
No one source includes all of the information students will need to respond to the culminating task. MRSA module engages students in five sub-tasks requiring integration of multiple sources: Creating a model of MRSA infection, Organizing evidence on emergence and spread of MRSA to determine relevance and magnitude of the problem, Creating a model for the impact of antibiotics on Staphylococcus *Aureus* populations, Creating a model for the causation of the emergence and spread of MRSA, Creating a model for the impact of preventions on the emergence and spread of MRSA. Interactive notebook accompanies text to provide a thinking and documentation space to foster science inquiry with texts; Inquiry Notetakers support students in synthesizing information across sources	The MRSA module provides a strong model of text-based inquiry in science, in that each text provides part of the information needed, but to complete the task, students must read and gather information from multiple sources. To construct this kind of inquiry based task for the water module, we developed working tasks and tuned them, based on what we found in the various textual resources available. Closely related to this is identifying a conundrum—a mystery or real problem—that is sufficiently complex enough that it can only be answered using multiple data points. Describing the water cycle is not enough, since most water cycle maps provide enough info for students to recite a descriptive definition.

4. Dynamic model of differentiation

MRSA	Water
Text complexity in science is high. Differentiation is therefore offered by providing instructional support in class to tackle the complexity successfully. Students read in class. The reading is not assigned as homework. Students engage in metacognitive conversations about their reading processes to build reading capacity. Students engage in collaborative meaning making to dynamically support comprehension; the teacher coaches this meaning making process. The texts are sequenced and students work with them iteratively so as to allow multiple entry points and multiple passes to build understanding. High interest texts (cases of MRSA infection among young athletes) and videos provide gateways into more complex science texts.	We learned from early implementation trials of the MRSA unit and materials that using metacognitive conversation as a dynamic assessment to inform instruction is a challenging practice for teachers to take up. This awareness allowed us to further scaffold tasks for students to further develop teacher guides and coaching notes. As an example, each and every reading task is structured around Think-Write/ Pairs talk/ Whole Group Share. As we work with implementing the unit, we intend to clarify the purposes of this routine pattern of instruction. Namely, that Think-Write is designed as a pre-instructional assessment (through teacher observation) of what students already know about the topic *and how to approach science reading* Paired talk is designed both as an additional opportunity for formative assessment (teacher observation) and to support acquisition of new discourses—both of science and literacy—through itinerant mentoring of pairs by the teacher. Whole Group Discussions are designed to serve to instructional purposes: first they provide additional opportunities to assess the development of student's science literacy and knowledge; secondly they provide opportunities for the teacher to respond to data about student performance gathered during Think-Write, Paired Talk and the developing whole group discussion. Each of the parts of this routine are structured and supported with notetakers to guide both the teacher and students through the process.

5. Guiding/Inquiry Questions are kept in the forefront

MRSA	Water
Three Inquiry questions guide the MRSA investigation: What is the relevance of Methicillin-Resistant Staphylococcus Aureus to me, my friends and family, my community? What causes Methicillin-Resistant Staphylococcus Aureus to emerge and increase? What can limit the risk of Methicillin-Resistant Staphylococcus Aureus?	Similarly, three Inquiry questions guide the water investigation: How are humans impacting water? Why is this impact important to me, my family and my community? What can people do to improve water resources?

6. Draw attention to puzzlements and conundrums

A challenge for design is constraining the problem space enough to make the inquiry manageable, but not constraining it so far that the inquiry becomes a disguised recitation task. Two characteristics were settled on for these modules: a good conundrum does not have a single correct answer, a good inquiry is one to which teacher may not know the answer.

MRSA	Water
Discourse and reading routines explicitly invite students' questions, puzzlements and conundrums about the phenomenon and the process of making sense of the texts and data. The inquiry notetaker columns (Source, Data etc., Implications, Making thinking visible) also explicitly evoke questions about the topic. Additionally, the Inquiry Questions focus students' attention on puzzling through the evidence for answers to questions that are compelling for them.	In the water unit, based on what we observed with the MRSA unit and to address students' needs in middle school, we built in more explicit supports for noticing and responding to puzzlements *about reading*. The function of the essential questions is to draw student attention to the puzzles and conundra—what mystery or conundrum emerges from the data and the texts?

7. Gateway Activities, hooks, or entry points

MRSA	Water
Nurse video leading to Inquiry Questions, Contagion movie trailer The MRSA module texts and activities include multiple entry points for students in the content and processes, for example, the movie about Connie and the texts about a student football player and lip piercing are engaging and raise questions about contagion and risk, the gross-out factor of MRSA infections sustains student interest, MRSA is frequently in the news, schools have enacted MRSA prevention policies, and students both read and create visual models as well as written texts. Throughout, students are asked explicitly to draw on their prior knowledge and experiences and to make connections with their own lives	Throughout, students are asked explicitly to draw on their prior knowledge and experiences and to make connections with their own lives In addition, the first texts pose problems that are partly familiar but likely will provoke questions. For example, students likely know something about water pollution, but may be surprised by the first two texts, which include photos of signs (one next to the Chicago river, near the neighborhood where students in the participating classroom go to school) which warn the public to avoid body contact with the water because of bacteriological contamination. Another text in this set claims, “To put it bluntly, the problem is poop.” How engaging might that be for sixth graders?

8. Cultural Datasets

MRSA	Water
We do not have datasets, but have framed questions around key processes of science reasoning that have parallels in students' everyday lives, that we believe will elicit datasets. For instance, we expect that by asking students how they size up a problem in their lives to connect to scientific exploration of the magnitude and relevance of MRSA, we will encounter some viable datasets for future use (how to prioritize and treat many demands for homework, for instance). Similarly, we are asking students to describe how understanding the cause of a difficulty helps them resolve it, en route to a reflection on how knowing the science of evolution or bacterial/human ecology or hygiene can help them develop effective plans for reducing risk of infection.	The focus on how to size up a problem is present in the water unit, but more implicit, raised through the "Why is this important…?" essential question and the framing discourse about problem-solution. Perhaps more relevant is the local data set around water use and pollution.

9. Consequential tasks that are meaningful to students and in the disciplinary context

MRSA	Water
The consequential task(s) for the MRSA module engages students in creating scientific models of MRSA infection, emergence, and spread and to develop local actions they can take to prevent (or limit) MRSA infection as well as argument to advance or challenge these models. The consequential tasks are always scientific. Each consequential task also involves consideration of the relevance of MRSA to the students and their community. Students will identify an authentic audience for their plan to reduce MRSA risk, consider what that audience needs to know about MRSA and what they likely current understand/misunderstand about the science, and address these in their final presentation. Presentations are open as to format. Students may develop lesson plans for younger students, make a YouTube video presentation, write or make an oral presentation to the school board, etc. Criteria for culminating projects will include explaining the magnitude of the problem (who should be concerned about MRSA and why), explain the science of MRSA evolution and transmission, propose a viable way to reduce risk, and explain why the plan will work.	Students create models of water use and pollution and make scientific recommendations about how to improve water resources in their local area to an authentic audience.

10. Routines for metacognitive conversations

MRSA	Water
Whenever students read they also engage in metacognitive conversations about their reading and reasoning processes to build reading capacity and collaborative meaning making to dynamically support comprehension. Some routines supporting metacognitive conversations are Think Aloud, Talk to the Text annotation routines, reciprocal modeling of science reading processes, building and revising reading strategy lists, building classroom word walls and concept development posters on targeted science vocabulary. Use of texts that can be annotated and use of the interactive notebook as a space to keep ongoing notetakers makes student thinking visible as they respond to and raise inquiry questions. Inquiry Questions notetakers provide a similar function while also supporting synthesis of understanding across texts.	To further support enactment of metacognitive conversation in the water unit, explicit scaffolds have been designed to support routines that with iteration demand complex interactions with texts, science content: Texts are embedded in an interactive notebook with prompts to make notations about reading and thinking. These annotations become the springboards for reciprocal modeling and discussion of first how we read (sense-making processes and strategies) and then what we read (content) These metacognitive conversations are captured on: 1. Posters (reading strategies lists, word walls, etc.) 2. Notetakers in the form of bookmarks listing reading strategies and sentence stems, which students continually revise in each whole group conversation and 3. Notetakers which capture scientific evidence and reasoning related to each text and synthesizing claims and evidence across texts.

11. Close reading of text to support engagement and reading carefully

MRSA	Water
See all the routines for supporting metacognitive conversations listed above. In addition to these, longer articles are chunked, with in class reading interleaved with small and whole group metacognitive conversations to support digging into text and collaborative meaning making. The MRSA unit engages students in repeated readings for different purposes to build their science reading repertoires: Language detective (science word and sentence, or discourse, level clarification, tracking conceptual change), identifying and collecting claims and evidence about the phenomena, reasoning and modeling (explaining) the infectious, evolutionary, and preventative processes.	Metacognitive conversations, both internal (through annotation) and external (paired and group discussions) are the primary supports for close reading. Reciprocal modeling is an essential tool to re-engage students in text by differentiating and scaffolding the reading tasks. Routines of making text notes about evidence and interpretation and making scientific claims set additional purposes for repeated close readings and intertextual sense-making. Additionally, texts are ordered from most engaging and least challenging to less engaging and more challenging, to allow students time to build persistence, stamina and a repertoire of reading processes they can use to engage thoughtfully as reading becomes more challenging.

12. Support for text-based discussion citing evidence

MRSA	Water
The MRSA module uses a set of supports for text based discussion and citing evidence routinely. Among these are Inquiry notetakers, Talking to the Text, teacher modeling and guided practice citing evidence, and constructing and critiquing models. The Inquiry note taker columns include Data/Evidence and Implications/Claims. Routines include Science Seminars, with small group sharing in Peer Review (critique sessions) prior to a Poster Session in which group work on explanation and model development from evidence in the texts is shared with and responded to by the class as a whole. Metacognitive conversation about what makes a good/complete/compelling explanation or model will follow each model/explanation making opportunity to give students opportunity to develop and internalize scientific criteria of evidence use.	In addition to Peer Review processes from the MRSA unit, the water unit treats text-based discussion as a support for close reading, since engaging in the social practice of text-based discussion requires actually reading the text. The curriculum guide for the teacher includes prompts to request textual evidence when conversation strays from the text, such as: • *Where in the text did you start to think that?* • *What in the text makes you think so?* • *Can you show us the evidence in the text that leads you to that conclusion?* • *Can you read the relevant section to us and tell us about your reasoning?*

13. Argumentation Templates to provide models for oral and for written argument

MRSA	Water
The Inquiry notetaker columns include Data/Evidence and Implications/Claims. Science Seminars, with small group sharing in Peer Review (critique sessions) prior to a Poster Session in which group work on explanation and model development from evidence in the texts is shared with and responded to by the class as a whole, offer repeated opportunities to construct and critique explanations, a key form of evidence in science. There is potential for additional argument templates or models. We are envisioning a set of talk stems for argumentation that evoke different aspects of arguments (claims, evidence, warrants, backing, and rebuttal), however, these are not yet drafted. We aim at the completion of the project to engage students in writing refutational-type texts for real audiences, perhaps using blogs or similar digital spaces to explain why, despite common misconceptions about widespread antibiotic use and/or hygiene and/or the evolutionary process, MRSA is a problem, what is causing it to increase in severity, and how best to prevent it.	To scaffold the task for this grade band and based on hypothesis about the challenges experienced in the MRSA unit of linking evidence to interpretation and then developing warranted scientific claims. we separated sense-making leading to argumentation into a scaffolded four-step process supported by notetakers and guided discussion: 1. Reading individual texts to develop a robust text representations for each text during the Think-Write, Pairs, Whole group metacognitive conversation routine 2. Develop a robust situation model for each text through the Source, Evidence, Interpretation routine 3. Develop intertextual situation models for all texts in a set through the Using Visual Models routine 4. Develop Scientific Claims –scientifically warranted claims about all the texts in a set (and later across sets) based on textual evidence

14. Participation structures that provide opportunities for student talk

MRSA	Water
The MRSA module provides multiple ongoing opportunities for student talk –student talk is at the center of the curriculum. Multiple structures are used flexibly to support student talk: Think-Pair-Share, Think-group-share, SOLAR listening (norm for small group listening), equity sticks, and gallery walks. The biggest support is the frequency of student talk about the reading and sense making process and the exclusion of teacher lecture, both planned and incidental.	Please see 10-13 above.

15. Ongoing assessment and formative feedback

MRSA	Water
Records of student thinking are created through instructional routines: Think Aloud, Talk to the Text, inquiry notetakers, models and explanations, final project. We'll need to specify how teachers use each of these to glean data and inform instruction dynamically. We expect this to be part of what we document every day as the intervention is taught as we meet with the implementing teacher. In addition, we have developed a pre/post individual assessment of a parallel topic – malaria transmission – to provide information about any change through the unit in students' reading for evidence and explanation/model building.	Based on experience with the history units, we intend to review student work daily with participating teachers to help them learn to analyze and respond to data about student performance gathered during metacognitive conversation routines.

III. First Iteration of Science Modules

In this section, the Modules are briefly described. Full module materials (teacher guides, student readers, student interactive notebooks) are available on the Project READI website and by request. See READI Curriculum Module Tech Reports CM.#19 and CM#20.

MRSA Unit – Iteration 1

The unit of study is designed to support:

- Teachers as they engage misconceptions students may hold regarding natural selection, adaptation, and evolution
- Students' developing scientific conceptions of evolutionary theory, which is an organizing principle of biology
- Students' positive dispositions toward reading and learning science by setting authentic purposes, leveraging relevant connections, and problem solving around significant issues of contagion and antibiotic resistance in students' school and home communities

Unit materials include:

- Teacher lesson plans,
- Student interactive notebooks that integrate texts with support for reading and reasoning: metacognitive notetaking, reflection and conversation prompts for peer groups, and modeling and explanation tasks,
- Inquiry question notetakers
- Pre/post assessments on a parallel topic and task

Iterative and spiraling pedagogical routines are:

- Warm-ups to activate schema for content, reading, and discourse, etc. These often include Gateway activities to build engagement as well as Cultural Modeling activities with elicited data sets.
- Think- Pair-Share to promote equitable participation
- Protocols for pair and whole group discourse (SOLAR, Popsicle sticks etc.,) to promote equitable participation
- Reading previews to build motivation and stamina for reading

- Strategic Teacher Think Aloud Model to elucidate reading and reasoning processes
- Paired Think Aloud with annotation to support development of strategic reading processes and facilitate collaborative meaning making
- Text annotation while reading to foster a discipline of meaning making alongside texts containing varied representations and to make thinking visible for shared inquiry
- Writing to learn/capture investigation in process through Interactive Notebook that accompanies unit texts
- Metacognitive Conversation about reading process to support development of strategic reading processes and facilitate collaborative meaning making
- Adding to the Reading Strategy List to support development of strategic reading processes
- Adding to the MRSA word wall (student selected words) to develop engagement with word learning, fluency, and content knowledge
- Adding to the Concept Building posters to develop discipline and content knowledge and track and monitor conceptual change
- Periodically writing and discussing responses to the Inquiry Questions and key concepts probes in the inquiry notetakers to consolidate learning
- Protocols for identifying evidence across multiple texts to synthesize concepts across multiple texts
- Construction of visual representations of data and models to develop science epistemology and content knowledge for science explanation
- Creating written representations of models and arguments to develop science epistemology and content knowledge for science explanation
- Peer Review (pairs meeting with pairs) of models and explanations to foster critique and argument about best explanations and use of evidence and to develop internalized criteria for science models and explanations
- Science Seminars to develop science epistemology and content knowledge for science explanation and to foster critique and argument about best explanations and use of evidence and to develop internalized criteria for science models and explanations
- A **culminating, consequential argumentation task** in which student groups develop a viable plan to for reducing the risk of MRSA infection in their own communities, address a real audience, and justify their plan on the basis of science evidence that it will be effective

Water Unit – Iteration 1

The unit of study is designed to support:

- Teachers as they engage misconceptions students may hold regarding where their water comes from, what it is used for, how safe it is, and how humans impact water as they use it
- Students' developing scientific conceptions of thermodynamics as it relates to hydrology
- Students' positive dispositions toward reading and learning science by setting authentic purposes, leveraging relevant connections, and problem solving around significant issues of fresh water resources in students' school and home communities

Unit materials include:

- Teacher lesson plans,
- Student interactive notebooks that integrate texts with support for reading and reasoning: metacognitive notetaking, reflection and conversation prompts for peer groups, and modeling and explanation tasks, positioned on facing pages to scaffold text annotation
- Inquiry question notetakers

Iterative and spiraling pedagogical routines are:

- **Warm-ups** to activate schema for content, reading, and discourse, etc. These often include **Gateway activities** to build engagement as well as **Cultural Modeling** activities with elicited data sets.
- **Think- Pair-Share** to promote equitable participation
- Protocols for pair and whole group discourse (**SOLAR**, Popsicle sticks etc.,) to promote equitable participation
- **Reading previews** to build motivation and stamina for reading
- **Strategic Teacher Think Aloud Model** to elucidate reading and reasoning processes
- **Reciprocal modeling**, in which the teacher dynamically guides metacognitive conversations in the whole group, by inviting students to share their thinking and reading processes and then models her thinking and reading processes in reciprocal turns with students

- **Paired Think Aloud with annotation** to support development of strategic reading processes and facilitate collaborative meaning making
- **Text annotation** while reading to foster a discipline of meaning making alongside texts containing varied representations and to make thinking visible for shared inquiry
- Writing to learn/capture investigation in process through **Interactive Notebook** that accompanies unit texts
- **Metacognitive Conversation** about reading process to support development of strategic reading processes and facilitate collaborative meaning making
- Adding to the **Reading Strategy List** to support development of strategic reading processes
- Periodically writing and discussing responses to the **Inquiry Questions** and **key concepts** probes in the inquiry notetakers to consolidate learning
- **Protocols for identifying evidence** across multiple texts to synthesize concepts across multiple texts
- Construction of **visual representations of data and models** to develop science epistemology and content knowledge for science explanation
- Creating **written representations of models and arguments** to develop science epistemology and content knowledge for science explanation
- **Peer Review** (pairs meeting with pairs) of models and explanations to foster critique and argument about best explanations and use of evidence and to develop internalized criteria for science models and explanations
- A **culminating, consequential argumentation task** in which student groups develop a viable plan to for improving water resources in their own communities, address a real audience, and justify their plan on the basis of science evidence that it will be effective

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Project READI
Core Knowledge Constructs Needed to Engage in Evidence-Based Argumentation from Multiple Sources in Science

Categories of Knowledge	Description/ Definition	Illustration

Epistemology	*Beliefs, values, and commitments about the nature of science that the reader draws upon*	• Science is an attempt to build understandings of the physical and designed worlds through constructed models, which are understood as *approximations that have limitations.*
		• Scientific findings are tentative and subject to revision.
		• Science knowledge is constructed incrementally over time and is influenced by (and in turn influences):
		  ○ Technology
		  ○ Theories and paradigms
		  ○ Cultural norms
		• Science knowledge is socially constructed, using peer critique and public dissemination to create scientific explanations that meet certain criteria:
		  ○ They are based on sound empirical data.
		  ○ They are parsimonious and logically cohesive.
		• Scientific findings have both practical and theoretical implications for science and society.

Inquiry Practices	*The practices of engaging in science inquiry. These practices are common to both first- and second-hand investigations. (There are additional practices associated with collecting first-hand data that are not listed here).*	Scientific knowledge is built by: • Developing coherent, logical explanations, models or arguments from evidence • Advancing and challenging explanations • Converging/corroborating evidence • Comparing/integrating across sources (and representations) • Evaluating sources and evidence
Overarching Frameworks/	*Unifying or General Concepts and Themes in Science*	• The College Board Standards for College Success (2009) list 7 unifying concepts that apply across scientific sub-disciplines (p. 1): ○ Evolution

Concepts/Themes		○ **Scale** ○ **Equilibrium** ○ **Matter and energy** ○ **Interaction** ○ **Form and function** ○ **Models and explanations, evidence and representations.**
Ways of Representing Information	***Prototypical ways of structuring/presenting scientific information***	**<u>Text Structures</u>** **Scientific texts may have different explanatory purposes:** • **Cause/Effect/Correlation** • **Problem/Solution/Findings** • **Proposition/Support** • **Sequence/Process/Chronology** • **Goal/Action/Outcome** • **Description/Definition** • **Comparison** • **Enumeration/Exemplification** • **Problematic Situation** **<u>Multiple Representations</u>** **Science texts convey meaning with multiple representations:** • **Diagrams** • **Equations** • **Charts** • **Tables** • **Videos** • **Simulations** • **Flowcharts** • **Models** • **Verbal (oral and written)**

		<u>Types of Sources/Genres</u> **Different genres are written for different audiences and purposes, and these have implications for their content and structure:** • **Raw data** • **Bench notes, field notes, journals or logs** • **Refereed journal articles** • **Personal communications such as interviews, letters, emails, conversations** • **Integrative pieces: Chapters in handbooks, advances in science series and refereed review articles, popular press articles** • **Press releases, news briefs, and online articles** • **Science fiction** • **Textbooks and trade books** • **Websites and blogs**
Discourse [Language Structures]	***Prototypical conventions of science texts***	• **Science texts contain distinctive grammatical structures such as nominalizations and passive voice.** • **Science texts contain technical and specialized expressions.** • Science discourse signals the degree of certainty, generalizability, and precision of statements. • Science discourse signals rhetorical and logical relations among ideas. • **Authors construct science texts for particular purposes.** • **Argumentation is a scientific discourse practice in which evidence is used to support knowledge claims, and scientific principles and methods are used as warrants.**