
Updated Design Rationale, Learning Goals, and Hypothesized Progressions for Text-Based Investigations in Middle and High School Science Classrooms

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Introduction

The Science Design work within Project READI focuses on the development of text-based science investigations, work that promises to make a unique contribution to the fields of science and literacy education. As defined in Project READI Technical Report #17, READI text-based investigations for science focus on explanation/model building (NRC, 2012) about science phenomena from multiple documents and scientific representations. The READI Science Design Team worked across sites and with teacher design partners to implement two interventions during the spring of 2012: The first of the READI Science modules, on Methycillin-Resistant Staphylococcus Aureus, or MRSA, was implemented in a 10th grade biology and 11th grade physiology classroom.

In addition, based on lessons learned from the first iteration modules and their implementations, the Science Design Team developed a mini-module focused on Reading Models to introduce students to the role of modeling in science, which was implemented in two middle school science classrooms. A middle school module on MRSA was designed and will be implemented this spring, along with a new pre/post assessment on a parallel evolutionary topic, pesticide resistant head lice. Revision of the MRSA module for high school is currently underway, with plans to implement the unit this spring. Finally, a high school life science version of the Reading Models in science module is also in progress. These modules share a common architecture based on the 14 design principles developed by the larger Project READI team and are designed to address the Project-developed core constructs of knowledge for science.

Design Rationale

Reading for understanding in science requires that students build a robust internal model of science phenomena from evidence and ideas in source materials. READI science modules 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; Cervetti & Barber, 2008; Chiappetta & Fillman, 2007; McNeill, 2009; Myers, 1992; 1997). We hypothesize that due to 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; Norris & Phillips, 2003). An explicit goal of the text-based investigation modules, then, is to re-socialize students to actively construct meaning with science texts and to reposition science texts as resources for science inquiry learning (Pearson, Moje, & Greenleaf, 2010).

Toward these ends, these modules offer abundant social and material support for active sense-making and a focus on explanation/model building (Gotwals, Songer & Bullard, 2012; NRC, 2012; Pluta, Chinn & Duncan, 2011; Schwarz et al., 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. Students' work with the module 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, module 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.

Since March 1, 2012, the READI science team has validated the initial designs of text-based investigations around these principles by conducting a thorough literature review on the topic of science argumentation. Argumentation in science results from the development of models and explanations for phenomena (Cavagnetto, 2010; Osborne & Patterson, 2011). As scientists communicate the results of their experiments or observations in the form of models and/or explanations, they must argue for the viability of their understandings by demonstrating how well their explanatory models fit the data, by drawing on and connecting their results to the existing body of science principles, and by considering alternative explanations and showing why they are less accurate, powerful, useful, or parsimonious (Bricker & Bell, 2008). Studies of science argumentation show that students as early as elementary grades can productively engage in making claims about scientific phenomena and finding evidence to support those claims (Chin & Osborne, 2012; Ryu & Sandoval, 2012; Sampson & Clark, 2008).

This research also shows that younger students have more difficulty linking claims and evidence than do older students, and thus need more support to make explicit the grounds for their explanations and understandings (Berland & Reiser, 2009; Manz, 2012; McNeill & Krajcik, 2011; Windschitl, Thompson, Braaten, & Stroupe, 2012). Looking across the research base convinces us that we are operating in the right design space for the development of E-B A interventions for middle and high school science. Science education reform projects focused on supporting students to develop explanatory models have approached this important project by providing students with frameworks for explanation, modeling, and argumentation, using datasets or hands on investigations as stimuli for modeling and explanation tasks (Berland & Reiser, 2009; Chin & Osborne, 2012; Passmore & Svoboda, 2012; McNeill & Krajcik, 2011). Very little of the work on modeling and explanation has been carried out in the context of science reading. Ford (2012) reports that simulating interactions between science authors and reviewers for a

scientific journal can support scientific sense-making discourse, and Norris and colleagues (Norris, Stelnicki, & de Vries, 2012; Phillips & Norris, 2009) have shown that using adapted primary literature resembling scientific writing increases the use of critical thinking skills with writing. However, argumentation studies have focused almost exclusively on hands-on investigations.

To develop students' proficiency in science-specific *reading for understanding*, we have developed and refined text-based investigations in science to promote science literacy and argumentation, working in a design research tradition (Brown, 1992; Cobb, et al., 2004; Reinking & Bradley, 2008). Text-based investigations must allow students to build enough knowledge of a phenomenon from texts to enable them to model and explain it. We reason that by engaging students in building their understandings from close reading of high quality science texts, students will examine and critique their own and others' models and explanations through the course of the science modules, thereby engaging in arguing to learn while at the same time learning to argue scientifically (Von Aufschnaiter, Erduran, Osborne & Simon, 2008). At the same time, such an approach engages students in the literacy practices of science as core scientific inquiry practices, as newly highlighted in the Next Generation Science Standards (NGSS, 2013).

Student Learning Goals for Evidence-Based Argumentation in Science

To inform the ongoing work of module development and focus for assessment, including formative assessment while teaching E-B AIMS in science, the science design team met in Chicago in May 2012 as a part of two days devoted to further defining the Project READI Intervention. The group brainstormed a set of learning goals based on the ongoing design work. Subsequently, a subgroup met to discuss and explore the learning objectives and how to measure them. The result of this work is the following list. As we work on modules and document classroom implementation, we plan to test whether these objectives need further articulation and refinement.

Student Science Learning Objectives

1. Engage in close reading of science information to construct domain knowledge-including multiple representations characteristic of the discipline and language learning strategies.
2. Synthesize science information from multiple text sources
3. Construct explanations of science phenomena (explanatory models) using science principles, frameworks and enduring understandings (big ideas) and scientific evidence.
4. Justify explanations using science principles, frameworks and enduring understandings (big ideas) and scientific evidence.

5. Critique explanations using science principles, frameworks and enduring understandings (big ideas) and scientific evidence.

6. Demonstrate understanding of epistemology of science through inquiry dispositions and conceptual change awareness/orientation (intentionally building and refining key concepts through multiple encounters with text); seeing science as a means to solve problems and address authentic questions about scientific problems, tolerating ambiguity and seeking “best understandings given the evidence”, considering significance, relevance, magnitude and feasibility of inquiry.

The Role of Text-Based Investigation Modules in the READI Intervention for Science

Ultimately, the READI intervention is envisioned as ongoing professional development accompanied by material supports and worked examples to support teacher uptake and implementation of the approach across the science curriculum. An impact study is being designed for which teachers will enact Evidence-Based Argument instruction to promote construction and critique of science explanations and models from multiple science texts in units spread across a full semester to test the impact of such instruction on student learning. The designed modules provide material resources for instruction as well as models to guide teachers’ instructional decisions in the interstices between modules.

Draft Learning Progression for Text-Based Investigation

As we build modules, we are endeavoring to be deliberate in progressive sequencing to build a set of skills and dispositions for student science learners. Modules thus are intended to deliberately provide “spotlights” on needed classroom instructional routines to build needed skills and dispositions and progress them over time in the classroom. Based on observations from the iterative design and implementation process, the science team has drafted and will continue to refine a progression to guide module development and instructional sequencing.

Progression Development. The READI Science Design Team convened a series of meetings to construct a progression of learning for students’ advancement of scientific literacy processes and dispositions for evidence-based argumentation. The progressions were intended as tools to guide teacher implementation of the science learning goals. Early meetings explored the possible scope of the progression. What kinds of learning needs to be included with a progression -- non-cognitive, cognitive, metacognitive? Should it include student learning only, or the teacher learning progression necessary to support student progress as well?

The first draft of the READI science progression posited an evolving scope of reading growing from single text to multi text, from engagement with text to practice of processes to performance of argumentation tasks. It also indicated the requisite teacher learning associated with instruction that would support students in these tasks. The draft progression was

anchored in the developed science modules. Observation of READI inquiry network teacher implementation of the designed modules had indicated the kinds of requisite learning experiences students would need to prepare them to engage productively in prolonged text-based investigations such as the MRSA or Water Purity science module. One finding from these observations was that students need to learn discourse norms and routines for text based, metacognitive conversations that support sense-making, building knowledge of science, and building meta-knowledge for science reading. Another finding from classroom observations was that students needed to learn about the warrants for argument in science. These same findings had already led to the construction of the Reading Models module as described above. The progression draft attempted to build in these threads as aspects of science literacy practice that would build over time.

Subsequent discussion by the Science Design team elucidated the necessity for greater specificity in the progression with respect to the READI science student learning goals. The resulting second draft narrowed the focus to student learning only, faded the prominence of existing READI science modules and shifted the framing to the READI science learning goals. The new draft explicated how each of the science learning goals progressed over a semester of instruction, supporting purposeful advancement of each READI science goal across time. Alignment of the progression along the science learning goals also facilitated cross comparisons among the disciplines, since other design teams were developing similar progressions.

Progression Description. The READI science progression is a framework for ‘on-boarding’ novice science readers into science reading practices, culminating in reading multiple science texts for evidenced based argumentation. The progression supports teachers who having completed READI teacher professional development are implementing instructional approaches that develop student science reading, specifically the READI science modules. The READI science progression is organized into six strands of learning, one for each READI science learning goal:

- Close Reading
- Multi-text Synthesis
- Construct explanations of science phenomena
- Justify explanations of science phenomena
- Critique explanations of science phenomena
- Science Epistemology and Inquiry

In the progression, each learning goal progresses over four learning phases, forming 24 specific learning goal phases populated by multiple incremental science learning goals:

- Building Classroom Routines To Support Science Literacy and Meaning Making
- Building a Repertoire of Science Literacy and Discourse Processes
- Deepening Scientific Literacy And Discourse Practices For Reasoned Sensemaking
- Utilizing Scientific Literacy And Discourse Practices For Disciplinary Knowledge Building

The READI science progressions are grounded in multiple evidences and guided by READI core constructs and design principals:

- READI network teacher interviews and reflections
- READI network teacher designs (lessons, curricular units, scope and sequences for developing student science reading their own classes)
- READI network teacher classroom observations of READi Modules and science reading lessons
- READI Baseline observations

In the 2013-14 school year multiple middle school and high school teachers in the READI science network are instantiating the READI science progressions in their specific science curricula to generate grade level specific instructional examples to instantiate the progressions as well as to provide feedback on the progression itself.

Example READI Science Progression

	Building Classroom Routines To Support Science Literacy and Meaning Making	Building a Repertoire of Science Literacy and Discourse Processes	Deepening Scientific Literacy And Discourse Practices For Reasoned Sensemaking	Utilizing Scientific Literacy And Discourse Practices For Disciplinary Knowledge Building
SLG -1: Close Reading	<p>Setting a purpose for reading in science and science learning.</p> <p>Introducing Annotation as persistent close reading practice</p> <p>Introducing Discussion of meta-comprehension in context of sense making</p> <p>Introducing Language for describing reading and reasoning processes.</p>	<p>Building confidence and range with science genre, text types and text structures (including scientific models).</p> <p>Previewing to set reading purpose and process based on topic, genre, text type, level of interest and level of challenge.</p> <p>Identifying and Handling Roadblocks while reading.</p>	<p>Set reading purpose based on text-based indicators of reliability and scope of content.</p> <p>Nascent Modeling Reading processes: attending to and clarifying/inquiring into the Science, phenomena, elements and relationships thereof, and model generation.</p> <p>Multi-text synthesis</p>	<p>Attending to scientific principles (theories such as mass-energy conservation, Hardy-Weinberg model) and Unifying Concepts of science (paradigms such as Evolution, Scale, Equilibrium, Matter and Energy, Form and Function, model and explanations, Evidence and representations) while reading.</p>
SLG -2: Multi-text Synthesis	<p>Reading multiple texts on same topic or related topics</p>	<p>Making connections to schema and in-text connections</p> <p>Building knowledge of key concepts across multiple texts</p>	<p>Attending to how multiple texts are connected (i.e. complimentary, additive, or even contradictory) and the affordances of various text types (i.e.</p>	<p>Viewing texts as investigations, setting purpose and inquiry for reading single and multiple texts. Attending to the new information afforded</p>

			personal anecdotes, primary data) Building explanations for inquiry questions across multiple texts	with additional texts and how information provided in those texts addresses the inquiry question
SLG-3: Construct explanations of science phenomena	<p>Developing Norms for Classroom Discourse that holds students accountable to one another's ideas</p> <p>Students begin to increasingly explicate their ideas and make them visible to the classroom and their peers</p>	<p>Making norms for reading, writing, talking, speaking for text based science inquiry / sensemaking discussion routine</p> <p>Increased attention to building off of one another's ideas, attending to the logical coherence of one another's claims.</p> <p>Constructing gists of phenomena from single texts treating the text as an authority (i.e. noticing causal or correlation relationships between elements)</p>	<p>Deepen language, representation and discourse patterns/conventions that attend to disciplinary norms for knowledge building. Attention to evidence, claims, and the links that one puts forth and that others propose within classroom discussion.</p> <p>Developing and making public disciplinary norms for model construction, justification, critique and revision</p> <p>Constructing models based on text evidence</p>	<p>Using disciplinary criteria for knowledge building as students engage in multiple cycles of reading, talking, and writing</p> <p>Constructing multi-text models from larger text sets</p> <p>Using models to predict implications of proposed solutions and answers to authentic science questions</p>

<p>SLG-4: Justify explanations of science phenomena</p>	<p>Citing text in sense making / meta-comprehension discussions. Reasoning and support based on authority (text, teacher, or one's own experience)</p>	<p>Identifying relevant evidence in single text that responds to inquiry questions Increasing attention to the distinction between evidence and inference in both texts and classroom talk</p>	<p>Identifying relevant evidence that informs the model while reading single and multiple texts Specifying how evidence informs the model Developing criteria for scientific models and explanations (writ large and for particular systems) Justifying models based on criteria for scientific models and reliability of text sources</p>	<p>Justifying explanations by appealing to scientific principles or unifying concepts of science. Refining explanatory models and explanations through careful attention to claims, evidence and reasoning</p>
<p>SLG-5: Critique explanations of science phenomena</p>	<p>Offering and tolerating alternative explanations, viewpoints, opinions in class discussions.</p>	<p>Disagreeing and offering evidence/rationale for it, Asking probing questions of each other in class discussions. Questioning while reading (to clarify, challenge or build knowledge). Increased attention to how the ideas presented in text "fit with" one's prior knowledge and other texts.</p>	<p>Offering alternative explanations in response to the explanations of others Using criteria for scientific models and explanations (writ large and for particular systems) as basis for critique (I think that part of the model may be wrong because ...) and consensus building. Critique models and explanations based on the purpose of the model</p>	<p>Critique the reliability of models and explanations based on the quality of evidentiary support (convergence, corroboration) Critique the scope of the model based on appeals to scientific principals and unifying concepts of science.</p>

			(the question it is trying to answer). Compare multiple, alternative models for single phenomena.	
SLG-6: Science Epistemology and Inquiry	Promoting the understanding that scientific findings have both practical and theoretical implications for science and society Taking inquiry stance as a basis for interacting with text	Viewing science findings as limited and tentative, based on available evidence Tolerating ambiguity and seeking the best understanding, given the evidence, while reading	Recognize that science knowledge is socially constructed by peer critique and public dissemination (advancing and challenging explanations/models) to create scientific explanations that meet certain criteria (based on sound empirical data, parsimonious and logically cohesive) as a basis for co-construction of knowledge while reading.	Recognize that science knowledge building is shaped by (and shapes) scientific principles (theories) and Unifying Concepts of science (paradigms) as a basis for building knowledge of these and using them as a basis for constructing, justifying and critiquing models while reading.

Draft READI Science Module Progressions Overview

Module #	Texts/Time	<i>Most Consequential Tasks</i>	Metacognitive Conversation Focus	Primary Literacy Learning Goals for Students	Primary Potential Requisite Teacher Learning	Continuing/ongoing Routines to be practiced between modules
Module 1: Founding a Science Reading Learning Community (proposed)	1 text related to current curriculum topic 1 day	Read one text Practice one routine for making their metacognition visible (think aloud or talking to the text) Instantiate and practice norms for reading and metacognitive conversation. Begin the Science Reading Strategy List Poster	Students practice noticing, writing about and talking about their own about science reading processes. Students practice norms for silent reading/writing, pair/small group talk and whole class talk.	To notice their own science reading processes. To learn language for describing science read processes. To learn processes for engaging in pair and whole class metacognitive conversations, and processes for hold other accountable for the doing same. Students learn that reading is a processes	To notice their own reading processes To read with student in mind To model their thinking processes using think aloud. To model, mentor and hold student accountable in taking up the practices needed for pair and whole class metacognitive conversation. To elicit student thinking	Routines and practices for reading and metacognitive conversation repeated with individual texts in multiple lessons. Update Science Reading Strategy List
Module 2: Focusing MC on particular science reading processes (proposed)	1 text related to current curriculum topic 1 day	Read one text Update Science Reading Strategy List Practice new particular science reading practices.	Above plus ... MC now foregrounds particular Close Science* Reading Processes pertinent for reading the text	To acquire and refine particular science reading practices (visualizing for clarifying and consolidation might be high leverage seeing that we are headed that way with the modeling work)	To orchestrate inquiry about particular science reading processes To enact a reciprocal model of particular science reading processes To read with students in mind to prepare an the recip. Model To support student to build and respond to	Routines and practices for reading and ‘focused’ metacognitive conversation repeated with individual texts in multiple lessons. Update Science Reading Strategy list

					peers comments in whole group	
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Sequence	Texts/Time	Most Consequential Tasks	Metacognitive Conversation Focus	Primary Literacy Learning Goals for Students	Potential Requisite Teacher Learning	Continuing/ongoing Routines
Module 3: Models Module (existing draft)	1 text about science models Multiple visual texts, include visual representations of science models. __ days (?)	Read multiple science texts Begin a science Models criteria List Update the Science Reading Strategy List Poster	Above and ... How do you make sense of visual texts, including models? How do you distinguish whether a visual texts is a model, picture, or other genre?	To draw on prior knowledge and reading to acquire additional uses for specialized language: model. To learn the purpose and criteria of science models To build knowledge of genre of visual science texts, especially visual representations of model. To agree/disagree with peers (teacher) based on criteria.	To facilitate pair and whole class metacognitive conversations supporting disciplinary reading learning goals. (i.e. using the medium of metacognitive conversation to advance students reading practices.)	Above plus ... MC about visual science texts, including models
Module 4: Reading with Modeling and science argumentation (proposed)	1 text explaining a casual model for a phenomena – containing only a few elements and links, maybe a cycle – not visual provided __ 3 days	Read 1 science text Develop a visual representation of Explanatory Model	Above and ... How to notice and analyze a science explanation while reading How to form and update own mental model while reading How to draw on criteria for a good model to assess own mental model.	*how to form and sketch their mental models How to identify evidence in text for model construction and critique How to discuss what their mental model has accounted for and what it hasn't How to note confusions? Questions they still need to resolve	to support student to give criteria based feedback on peers mental model to argue for/against particular model 'constructions' based the warrants of criteria for science models and drawing on texts for evidence.	Above plus ... Identification and interpretation of evidence for model construction and critique. Text-based construction and critique of science models.

Sequence	Texts/Time	<i>Most Consequential Tasks</i>	Metacognitive Conversation Focus	Primary Literacy Learning Goals for Students	Potential Requisite Teacher Learning	Continuing/ongoing Routines
Module 5: Water Module (existing draft)	___ days	Develop a visual representation of Explanatory Model for how humans impact water Propose and argue for a course of action based on the science model	How to notice and analyze a science explanation while reading How to form and update own mental model while reading How to synthesize cross text information into a coherent science model? How to draw on criteria for a good model to assess own mental model.	Cross text synthesis	To support students in cross text synthesis of evidence into science model construction	Above plus multi text synthesis.
Module 6: Middle School MRSA (existing draft)	___ days	Develop a visual representation of Explanatory Model for how SA became MRSA Propose and argue for a course of action based on the science model	Same as above	Same as above	Same as above	Same as above

Ongoing Teacher Inquiry Network Contributions and Participation in READI Design Teams

In California, there are middle and high school science teachers in the Teacher Inquiry Network working on implementation and documentation of group-designed modules, as well as in working to implement the design principles for science E-BA across the school year in the topics they study. These teachers submitted an argumentation unit from their Winter/early Spring instruction of 2012 at the last Inquiry Network meeting of 2011-2012. Several of the submitted units demonstrated key aspect of the design principles. For example: 1) a unit on earthquakes generated by a student's inquiry question, "Should we be concerned that California has many small earthquakes every day?" for which students read multiple sources and used data from the USGS to respond to this question with their own explanation; 2) a unit on genetics responding to the question, "What living terrestrial animal is the closest relative to whales?" based on examination of the evolutionary records, gene mapping, and readings of multiple texts; 3) a unit a partnering teacher designed after implementing the MRSA unit on the causes, risk factors, and potential ways to reduce risk for diabetes.

Teachers in the Inquiry Network thus demonstrated their understanding of the intervention in their independent module development. To further identify teachers for close documentation among the California science participants, Project READI team members have conducted classroom visits to observe the pedagogical routines teachers have established in their classrooms, the culture for learning in place, and the role given reading in the science curriculum. From these observations, the team selected a few teachers to observe more closely as they implement science team-designed modules as well as across the year as they implement E-B A instruction in their curricula.

As a result of this selection process, there are two groups of teachers participating in the science design work drawn from California Inquiry Network participants: a middle school group focused on Earth science, and a high school group focused on life sciences including Biology and Physiology. In a participating middle school, two Inquiry Network teachers are developing modules for the entire year across the grade levels and we are not only documenting their design work but also are in their classrooms to observe and film frequently.

In addition, the science teachers meet as a sub group during the Teacher Inquiry Network sessions. This year, the team has been pursuing the development of explanatory models of science phenomena, and how to support students in constructing and critiquing models, both from text and from hands on investigations. They have been conducting inquiries themselves, pushing to model phenomena and see what they do as science readers and thinkers to do so. Stepping back from this inquiry, they have focused on designing instructional routines to support their students. These instructional routines constitute a resource for the ongoing module development and enactment of the READI science team.

In Chicago, science teachers have met for part of the day during the day-long sessions as a disciplinary group. The theme for the year has been assessment, based on defining learning

goals for each disciplinary group. Initially, the focus of the work in the science group was to define what we mean by scientific argumentation. The group of science teachers worked together to draw out what they think science argument is about -- that it involves making claims and a critical analysis of the sources you use to back up that claim. In this discussion teachers were questioning what part of this process of generating claims is actually argumentative -- and that without opposition, it is difficult to describe this activity as argument (rather than something like interpretation from evidence). Some teachers talked about argument as struggle, while others thought it could be just about the process of building knowledge. Out of this conversation the group generated a model of science argumentation on the white board and then also pointed out that norms need to be established in order to engage in these conversations. The group also began to draft a conceptual definition of science argument together as a group.

Subsequently, science teachers focused in network meetings on generating a progression, from grades 6-12, of what evidence-based argument might look like over time. Based on CCSS for the grade bands, the science group identified overarching 'themes' or strands of development in evidence-based argumentation, and then mapped backwards to define what these strands might look like at grades 6-8, 9-10 and 11-12. We worked in small groups and then convened together to talk about the different themes and progressions we generated in two small groups, and then consolidated this into one large conceptual definition with grade level specifications.

Some of the participating science teachers in the Chicago Teacher Network are also working with the READI design team to design and implement modules in middle and high school science classes, as in California. To the extent possible, the design teams attempt to engage teachers from across the sites in design collaboratives and conversations.

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