Studying the Implementation of Text-Based Investigations on MRSA in High School Science Classrooms: Lessons from Collaborative Designed Based Research

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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.

Introduction

The Project READI science design team engaged in iterative design and refinement of the MRSA module for high school for three years. The module instantiates the design approach described in Project READI Technical Report #17 as a text-based investigation to promote scientific argumentation from multiple sources in order to develop students' capacity for reading for understanding in science. Building on prior work of Greenleaf and colleagues (Greenleaf, Hale, Charney-Sirott & Schoenbach, 2007), development of the initial MRSA module began in 2011 with the selection of a text set and the creation of notebook materials (See Project READI Technical Report #17 for additional information). This iteration of the unit consisted of 15 texts, an interactive notebook, and tools for science reading strategies and science discussion talk stems.

The MRSA module was implemented in high school classrooms to further several READI research and professional development goals focused on increasing student disciplinary reading and thinking skills in science. It has served as a means to expand and refine our theoretical tools for understanding text-based instruction in science argumentation, and has improved our lens for analyzing teacher practice and student work.

Implementation took place in differing high school science classes during the second and third year of the project. This technical report details the lessons learned from these implementations and the refinements made to the module, and as a result to the text-based investigation approach, over time. By the end of the third year of the project, the science design team had articulated student learning goals and sequences of instruction to support teachers and their students in taking up the practices promoted by this approach to disciplinary literacy and argumentation. The refinement of the MRSA module both fed, and was fed by, these additional tools.

Collaborative Design-Based Research Methodology

With the input of science teachers in the California Teacher Inquiry Network and the partnership of teachers who agreed to implement the MRSA module, we conceived of the science design work in Project READI as a type of design based research (Barab, 2006; Brown, 1992; Cobb, et al., 2003) that is particularly collaborative in nature. Researcher-teacher partnerships that characterize collaborative design work have the potential to break down the gap between the worlds of research and practice that may be an obstacle to educational reform (Easton, 2013; Klingner et al., 2013; Ormel, et al., 2012; Penuel, et al., 2011; Roderick et al., 2009; Voogt, et al., 2015). Collaborative design research simultaneously focuses on improving learning environments of classrooms and creating professional learning practices that support teachers in designing and implementing these reforms (Cobb, et al., 2013; Cviko, McKenney, & Voogt, 2014; Ormel et al., 2012; Penuel et al., 2011; Penuel, Gallagher & Moorthy, 2011). Rather than deliver an intervention to teachers with the goal of having teachers execute it exactly as it was designed (Cviko, et al., 2014; Odam, 2009), teachers in design collaborations work together with researchers to co-design, implement, and study the effects of educational innovations and how to make them work within particular authentic, richly complex contexts (Klingner et al., 2013; Ormel et al., 2012).

By engaging science teachers as knowledge generators alongside researchers in the collaborative design team, the research was oriented toward productive mutual adaptation to help ensure that instructional design of project modules were informed by teachers' experiences and expertise, and that the affordances, challenges, and issues teachers and students face when engaging with new instructional practices entered into the process of designing the text-based investigation approach (e.g. Penuel et al., 2011; Voogt et al., 2015). We intended the collaborative design research to play a dual role of producing new knowledge and improving educational practice. Over the three years, we carried out two cycles of implementation and refinement before integrating the MRSA module into an efficacy study as part of a sequence of instruction instantiating the text-based investigation approach. This technical report summarizes the lessons learned and refinements made during these cycles.

Cycle One: Implementation and Documentation of MRSA Module in 9th Grade AP Biology and 11th Grade Physiology, Spring 2012

The MRSA module was the first of two E-B AIMS modules for text-based investigation developed to support argumentation from multiple texts in science in the winter and early spring of 2012. MRSA had been developed with the ongoing input and collaboration of science teachers in the California Inquiry Network. Having designed the initial unit materials, lesson plans, and pre/post assessments, we secured agreements to implement the full or partial unit from two high school life science teachers, collected positive consents from their students, and documented the unit daily in two high schools, one in California and one near Chicago. Implementation and documentation began in the spring of 2012. MF, an honors biology teacher in the Chicago area, was able to implement a part of the module, for two weeks. AJ, a physiology teacher in Oakland, CA, implemented the entire module from March 22 to April 24, spanning the spring break. AJ was also a member of the California Teacher Inquiry Network science design team. Both are highly knowledgeable and highly regarded science teachers.

As the collaborating researchers, we met with the science teachers in the California Teacher Inquiry Network to co-design the module. These meetings were audio and videotaped, with one of us taking field notes whenever possible. Planning sessions with implementing teachers in both California and Chicago were also audiotaped. These interactions fed into the instructional design, materials, and pedagogical approaches embedded in the module, and into the plans for implementation. As the MRSA module was implemented, a team of two READI researchers attended each day to observe, document, and discuss the lessons. The research team took field notes and audio and videotaped the teachers and student small group interactions during the lessons. After the instruction, the team debriefed with the classroom teacher about any changes of note in the lesson plans and in anticipation of how, if at all, teaching plans for the next day may be adjusted to meet student needs. These debriefing sessions often included instructional coaching and clarification of lesson activities with the teachers.

As MF and AJ taught the MRSA module, they received ongoing coaching from a member of the science design team. In part, this was to offer ongoing support in response to the teachers' expressed needs. As the meetings with teachers and the module implementation proceeded, however, it became apparent that the enabling pedagogies at the heart of the unit – close reading of a variety of science texts and representations, developing and refining models of science phenomena, explanation, argumentation, discourse practices to support explanation and argumentation, and classroom cultures that held students accountable for doing the intellectual work while providing support for them to grapple with complexity – were new to both these teachers and their students. Ongoing coaching and support to solve problems of pedagogical practice were therefore vital to the successful implementation of the module. This level of need for pedagogical development was evident across the subject areas and module implementation and underscored Project READI's focus on designing professional development for teachers in order to put needed instructional approaches in place to support E-BA from multiple texts in the disciplines. (See Curriculum Module Tech Report CM #23 Life Sciences: The Spread of MRSA, Sp 2012.)

Analysis of Implementation/Design Research: Strengths and Needed Improvement

Over the course of documenting the module implementation in AJ's and MF's classes, it became clear that instruction in these classrooms had not previously focused substantively on how to read and make meaning of science texts. Few productive discourse structures were in place to assure that students could build knowledge collaboratively about science information. While students had been asked to explain and even to present arguments in AJ's high school physiology classroom, they had never engaged in interactive argumentation about the adequacy of their models and explanations with others in the class. They had not used models and modeling as thinking tools for building knowledge but were instead used to using visuals to display knowledge. Therefore, routines for discursive argumentation were lacking, as were metacognitive routines for making student thinking public and assessable. In addition, expectations and accountability for student intellectual work were aimed very low in the implementing high school classrooms.

In general, the pedagogies that would enable close reading of science texts to construct and critique explanatory models were notably absent in the implementing teachers' classrooms. Intervention classrooms thus demonstrated many of the same features of instruction, including instruction around science texts, that had been found in the classroom observations conducted in year one of the study.

For example, classroom observers kept reflective journals during the implementation of the MRSA unit in MF's class. The following things came to our attention during observations during the first sub-module of the unit.

- MF expressed both a sense of adventure and discomfort facing the task of turning investigation over to students, using texts as primary sources of information. He found it difficult to let go of front-loading content and struggled with pacing, finding it difficult to give students time to think and reason and discuss science ideas as they read the pieces in the curriculum.
- As the unit progressed, MF seemed to be making a conscious decision to hold back and let the students talk and develop their ideas. He said he was trying and that this was a really foreign experience and felt uncomfortable.

- The fact that MF shared the classroom with several other teachers made the posters difficult to navigate, in particular the more permanent posters as well as the word wall. Some adaptations to this might need to be made for teachers who are not in a permanent classroom. One idea might be using technology like smartboards to display posters rather than having a physical poster on the wall.
- For this teacher, having lesson goals for each class was really important. It helped with organizing the lesson sequence and freed the teacher from having to refer to each individual step in the lesson sequence.
- Students were very engaged with the topic and with the tasks that comprised each lesson.
- When constructing their models, students did not refer to the evidence they had gathered from the articles they had read until they were explicitly asked to refer to their notetaker and the articles for evidence. This underscores the role of such a coherence-building notetaker and also the need for explicit support for using evidence deliberately in model building.
- Students also did not give substantive feedback during the gallery walk to view models and explanations until they were told their feedback had to relate to the two questions the models were trying to address. Initially, many comments were about the drawing or the art work at a very superficial level. Again, students' lack of familiarity with substantive intellectual work may be in evidence here. They are just beginning, in this first part of the unit, to construct criteria for what makes a good model and explanation, as a class. This focus on the superficial indicates the necessity of this explicit criteria-building in order to develop new understandings of "what counts" in science.
- Students were very comfortable sharing their reading strategies and had a number of strategies to share. Most of the strategies, however, focused on vocabulary rather than comprehension or meaning making. Again, students' lack of experience making meaning together with science texts may be in evidence here

Built into the MRSA module was an inquiry orientation in which students are the ones who need to do the thinking, and engage with text in personal ways, then engage with others to expand ideas and formulate questions and claims, to delve deeper into text in order to identify the evidence that supports their claims and argument building. Ultimately, the students are to develop recommendations supported by evidence in their close-reading tasks, while building from synergy in classroom group discussions, interest developed over time, with ongoing support from teacher modeling, probing, and monitoring, as well as interaction with peers. The role of teacher thus was to become one of facilitator/coach as students carry out text-based investigations. As the observations indicated, this proved to be a challenging shift in instruction. At the same time, this teachers' experience suggests that the unit, as constructed, may have promise as "educative curriculum" for science teachers. It also raises the inherent tensions of content coverage and instructional time necessary for students to learn to read for understanding in science.

Implications for Improvement

Documentation thus pointed at the importance of ongoing professional development for teachers, as well as ways to make particular instructional approaches stronger and more salient. We became aware as well of the need to make material supports for teacher implementation flexible and differentiated, since teachers may be entering the modules having had varied levels of experience with key instructional routines, or may be implementing the modules at various times of the year when their students' experience with these routines may vary. For example, depending on students' grade or reading proficiency levels and their experience with close reading/think-aloud/student talk and group interactions, their interpretation skills vary and may need differing degrees of instructional support. For developmental reasons, in middle school one might expect that more instructional supports would be needed, yet when high school students are in classes where it is not the norm to work with textual information in this manner, a similar level of scaffolding may need to be included in the intervention as well as explicit guidance and formative assessment methods provided so teachers can determine to what degree they should provide supports and modeling, knowing the strengths and needs of their students.

These design considerations are more easily dealt with in the context of ongoing professional development but also point in the direction of needed material support and further design work for E-B AIMS in science.

In sum, both professional development and material support needs to build teacher capacity for responsive and adaptive teaching. Teachers need to be able to navigate and calibrate their support for students in key arenas including the following:

- Building student investment in the investigation by highlighting the magnitude and relevance of science phenomena - the 'why care' piece of module design - seemed to need more support/modeling or bridging to engage students from the get go.
- To this end, the task set up is key, so that the investigation across multiple texts appears as a puzzle with pieces that are needed in order to make a whole - more overt and repeated statements about the need of multiple texts to come to a whole understanding may be needed.
- Teachers' roles in terms of which elements of the unit need modeling and when must draw both on a robust pedagogical repertoire as well as observation and formative assessment of student readiness for particular kinds of intellectual work: modeling/supporting the initial processes for literacy and making sense, developing close reading habits, modeling the kind of responses to tasks that are acceptable, knowing when to probe further so students know where they stand and what they are accountable for, etc.
- Teachers need to reinforce close reading skills for students to learn to differentiate between how to simply pull out information (as typical comprehension tasks require) and how to find relevant information that applies to the investigation task, finding the right balance between modeling and allowing students to engage with text and find relevant information to corroborate and support claims. During the modules implemented with students who were relatively inexperienced with inquiry tasks, this needed more explicit instruction.
- Professional development and material supports need to provide scaffolds for classroom teachers to enable them to more expertly elicit students' thinking, model claim building, build trust in the class inquiry culture, change typical classroom roles that students are used to, let go of control, emphasize what students think and place value on the quality of responses they give.

- Teachers need support to develop the classroom discourse routines that will enable students to collaborate on intellectual work, construct and evaluate explanations and models, and engage in scientific argumentation.
- Teachers need both tools and professional development aimed at monitoring student work – another key emphasis during instruction.

These considerations helped the science design team to refine both the professional development for teachers as well as the pedagogical supports built into the modules.

Analysis of Videotaped Implementation MRSA Module in 11th Grade Physiology

Despite these documented needs, much progress was made in the implementation of text-based investigations for E-BA in science. An analysis of instruction in AJ's high school physiology class demonstrated a radical shift to science inquiry as the focal point of instruction rather than absorption of science information and facts. Student learning about MRSA was mediated entirely by textual resources – both the interactive notebook and the MRSA texts – with text-based discussions and collaborative sense making of the science content gleaned therein guided and orchestrated by the teacher, AJ. This stands in stark contrast to what is typical in science instruction, and was typical of AJ's instruction up to this point. Typically, and previously for AJ, science content is largely delivered by the teacher, through lecture and PowerPoint presentations and demonstrations. Close reading and investigation with science texts and even hands on science investigations are rare experiences in science classrooms (Barber & Cervetti, 2008; Kracjik & Sutherland, 2010; National Research Council, 2007).

To discern the emphasis in AJ's instruction, classroom videos for each day of the 4 week unit were parsed into segments of instruction based on shifts in instructional task, using NVivo, a qualitative data software system. Each segment was then coded with a set of instructional descriptors developed for analysis of the Year 1 classroom observation data. This enabled us to see the architecture of lessons, including the source of science content informing the lesson, the time spent on particular learning tasks, the emphasis of instruction, and instructional grouping. Use of these codes enabled us to compare the instructional experience offered students during AJ's MRSA unit to the baseline observations conducted in year 1 of the study (see table 1, below). Additional codes were developed to capture instructional foci unique to text-based investigation modules and those that specific to design principles which did not necessarily occur in the baseline observations conducted in science classrooms in Year 1.

Table 1 shows the proportion of lesson time spent in various instructional groupings and instructional tasks and their emphases. The 20 videotaped lessons represent approximately 14 hours and 44 minutes of instructional time. Segments of instruction coded with any particular code were summed across these 20 lessons to calculate the proportion of time across the 20 lessons spent in particular groupings or devoted to particular task foci. Clearly, this is a very blunt measure of instructional focus during the unit. However, it does indicate progress on key activities theorized by the project to relate to student learning to read for understanding in the disciplines.

In particular, text was the *only* source of science content during AJ's implementation of MRSA, a dramatic difference from baseline science observations. AJ was never observed delivering content to students about the science topic itself during the MRSA unit. More instructional time was spent in collaborative group arrangements, either pair or small groups, during the MRSA unit than during baseline observations, with less time devoted to individual activity. Explicit support for learning to engage in collaborative learning during the unit is also evident in the time coded Discourse Routine. AJ's modeling, guidance, and support, along with giving directions for tasks students were to complete in pairs or groups, reflect her orchestration of collaborative sense-making with MRSA materials and texts.

These differences in instruction indicate important distinctions in how work was getting done in the MRSA class compared to science classrooms observed at baseline. But equally important were the striking changes in the learning tasks students were assigned during the MRSA lessons compared to baseline observations, as shown in Table 1. With text being the main source of content, including the directions for student work embedded in the Interactive Notebooks, close reading took a much more central role in learning tasks. Interactive Notebooks mediated students' interactions with source texts about MRSA as well as with one another and with the teacher. In addition to this ongoing mediation, close reading itself became a focus of instruction: how to read a particular text, what to read for, what kind of difficulties students expected with particular texts, what strategies they used while reading, what strategies the teacher demonstrated with Thinking Aloud to find evidence for a claim, and so forth. Students also spent time individually engaged in close reading of MRSA texts and more frequently, used the products of the reading in discussions with peers and the class. Close reading tasks were never observed in baseline observations of science classes.

Table 1

Segment Code	**Year 1 Science CRs**	**AJ's MRSA Unit**
Content Delivery		
Teacher *Teacher lecture, demonstration or PowerPoint. Teacher has done the work of understanding and organizing science material and delivers science information to students.*	36%	0%
Working with Text *Content presented through text(s). Text is defined broadly to include a wide range of materials, including graphics, etc., from a wide range of courses. In MRSA, tasks involving working with Interactive Notebooks and Notetakers were also*	55%	94%

coded as Working with Text		
Instructional Grouping		
Whole Class *Teacher interacts with the whole class at once*	55%	57%
Small Group *Students divided into small groups that they generally run themselves*	17%	22%
Pair *Students work in pairs*	10%	15%
Individual *Students work independently*	22%	7%
Instructional Interactions		
Giving Instructions *Used exclusively for setting up a task*	7%	21%
Modeling, Guidance and Support *Teacher offers modeling, guidance, and support for students to do the work of reading and learning during the segment of instruction*	59%	74%
Housekeeping/Management *Procedural focus related to general classroom business or non-instructional activity, including passing out and collecting materials and student work, changing groupings, announcing school activities, dispensing rewards, etc.*	15%	5%
Task: Opportunity to Learn		
Close Reading *Task requires students to approach texts to understand them vs. to find information. Involves*	0%	53%

interactive negotiation of meaning at the local and global levels to unearth and evaluate possible meanings, individually or collaboratively. In addition to the text set about MRSA, students were routinely asked to read and clarify the meaning of Interactive Notebook prompts with their partners and groups to socialize students to carry out science inquiry rather than await information from the teacher. These were coded as Close Reading.		
Cross Textual Analysis *Task/activity involves synthesis, evaluation, or critique of information from multiple texts. In MRSA unit, synthesis occurred as periodically completion of MRSA Inquiry Questions Notetakers, refining key concepts and developing models and explanations of MRSA infection*	0%	38%
Argumentation *Task asks students to make a claim or assertion that is supported by evidence that connects to the claim in a principled way. Argumentation tasks are framed as inquiry into multiple possibilities and/or viewpoints.*	0%	37%
Disciplinary Knowledge Building *Task references overarching frameworks, concept and themes of the discipline. Disciplinary knowledge building tasks often ask students to identify or apply disciplinary epistemologies, frameworks, concepts and themes to specific cases, situations or contexts. In MRSA, conducting inquiry to understand the cause and interrupt the spread of the disease*	66%	70%
Fact Acquisition *Task focus is testing understanding, recall or rote learning with little or no opportunity for*	24%	0%

sensemaking. Focus is on learning information		
Writing *Includes both writing for knowledge building and knowledge showing tasks*	52%	42%

Segment Code	**Year 1 Science CRs**	**AJ's MRSA Unit**
New Codes Reflecting Text-Based Investigation Module and Design Principles		
Inquiry orientation/ Epistemology *Task framed as inquiry into cause, significance, or prevention of MRSA infection with orientation to finding evidence to explain cause, decide on relevance, and justify a course of action to reduce MRSA infection and spread*	*NA*	53%
Modeling/visual representation *Task asks students to develop a visual representation describing a scientific process or to represent visually their understanding of infection, relevance, and/or cause of MRSA*	*NA*	21%
Text-Based Discussion *Task requires students to use information and evidence from texts during a discussion focused on understanding the scientific phenomenon*	*NA*	14%
Word Learning *Task explicitly involves attention to word learning and word learning strategies*	*NA*	8%
Metacognition *Task explicitly models or requires students to articulate thinking, reasoning, reading processes*	*NA*	28%

they use during the segment of instruction		
Discussion Routine *Segment of instruction involves explicit focus on how to carry out discussion with peers, including purposes and roles for the discussion*	*NA*	35%

MRSA tasks periodically required students to integrate and synthesize knowledge from multiple texts when pulling together evidence, mapping new learning onto key concepts, and addressing the Inquiry Questions of the unit. Similarly, learning tasks also periodically required students to make claims about MRSA infection, its significance and scope, its cause, and its abatement. Argumentation tasks were explicitly designed into the unit and Interactive Notebook and segments devoted to argumentation spanned 37% of the lesson time during the unit, whereas argumentation *never* occurred in the baseline observations of science classes.

Tasks involving metacognition, modeling, text-based discussion, and word learning strategies emerged in relation to close reading and use of the MRSA texts as learning tools. These codes were not used in the baseline observations but were important to code since they are a focus of READI science design. Table 1 provides descriptive definitions of these task codes.

Finally, it is important to note that the focus on disciplinary learning was not undermined as a result of the focus on text reading and sense making. Instruction during the MRSA unit was every bit as focused on science learning as was baseline instruction. However, in AJ's instruction during the MRSA unit there was zero emphasis on acquiring, extracting, or reciting facts alone, something that occurred 24% of the time in baseline science classes. Instruction was focused meaningfully and intentionally on the epistemology of science (70% compared to 66% in year one observations), in the form of constructing understandings of the cause of MRSA infection and the emergence of bacteria resistance. Overall, then, students' opportunities to learn Evidence-Based Argumentation from multiple texts in science were dramatically increased during the AJ's implementation of the MRSA unit.

Repositioning Texts, Repositioning Students

The high proportion of time (53%) coded as Epistemology/Inquiry reflects this orientation to learning during the MRSA unit. Lessons were designed to engage students in building knowledge about MRSA over time, driven by inquiry questions they would predictably pose in response to the readings offered over time. Making this shift to position texts as sources of information and knowledge meant that students would need to tolerate not knowing the answers to questions immediately, but rather expect to learn the answers as they engaged with the unit and texts over time. When students are socialized to traditional classrooms where they receive information from teachers, not being given answers can be unexpected and unwelcome.

The following discussion took place early in the unit after students had read a news article about a young man who had a lip piercing and almost died from a subsequence MRSA infection. The case story comes early in the unit to provoke interest as well as inquiry questions. Students have individually read, then discussed their questions about the story with a partner, when this whole class discussion ensues.

> AJ: I hear a lot of different comments. [Starts documentation of students' "piercing questions" on the story.]
> Susanna: What I don't understand was if MRSA is a drug resistant infection then how did it get on the needle? If you would have sterilized the needle would it still be on the needle?
> AJ: If she had sterilized the needle, would he have still have gotten MRSA? [writing]. James.
> James: Why would he pierce his lip if he's sick? You know, if he's sick..
> Ss talk amongst themselves.
> S: How do you get MRSA?
> AJ: Okay, let's quiet down. Some of you are sharing your ideas so fast I can't keep up with you. So let's do this orderly. Thank you. Porter?
> Porter: At first I put like, how rare is it? Then I thought again and said, how common is it?
> AJ: And what is "it"? [T has been documenting throughout]
> Porter: MRSA
> AJ: How rare is MRSA, then how common is MRSA? [writing] Kelly.
> Kelly: I was going to ask you a question, how do you get MRSA?
> AJ: How do you get MRSA? [starts to write question]
> S: She's asking you actually, not for the board.
> AJ: I understand.
> Alicia: I have a different opinion from the article.
> AJ: And I'm going to actually, before I take Alicia's question and then Keila's, I'm going to address Kelly's prompt with her question, No I'm asking you. Part of this unit is not for me to give you the answers. Part of this unit is for you to learn how to manipulate the information that you can solve the question yourself. So Kelley I will come back to you, but I'm going to go to Alicia, then Cat, then you.
> Alicia: So, should people avoid taking antibiotics to prevent MRSA?
> Kelly: Is MRSA a more complex version of a staph infection?
> Cat: Does MRSA affect the joints to the point that they deteriorate?
> Susanna: Why did he need surgery in his knees and hips if it was in his lip?
> Ss in side conversation: We are talking about MRSA and we don't even know what it is. Do you know what MRSA is? [S begins reading aloud in a quiet voice from a text]
> S: It is a staph infection.
> AJ: [addressing side conversation] I am experiencing major distraction.
> Susanna: How did it spread to legs and hips?
> Dustin: What is with the antibiotics? It mentioned that the antibiotics aren't helping. Is it the use of the antibiotics diminished their usefulness?

As this class discussion indicates, designing new environments for student learning necessarily entails disrupting the status quo, redesigning in a sense what students have come to expect. This is not necessarily easy to accomplish. Clearly, some of AJ's students were initially discomfited by not knowing the answers to their questions. They indicated their expectation that AJ, as the classroom teacher, would answer their questions, appealing to her former role as the primary source of science information in the classroom. When AJ did not respond as expected by these students, they were clearly surprised.

In addition, the description of the architecture of lessons taught by AJ outlined in Table 1 should not be taken to imply that all students were productively engaged and therefore experienced this learning equally. We know in fact that uptake by students was very uneven during the MRSA unit, coming as it did in the spring of the year after students were well used to different classroom norms and frankly, low expectations for the rigor of intellectual work they would do. Comparing the instruction on offer during MRSA to baseline observations of science classrooms does, however, show profound differences in students' opportunities to learn in science with the E-BA designed unit.

Moreover, these changes in pedagogy, once experienced and valued by classroom teachers, may help to transform regular instructional units when teachers are not implementing the designed modules. Following her experience with MRSA, AJ designed a text-set and unit for student inquiry and recommendations about reducing the incidence of diabetes, with a design parallel to the MRSA module.

Administration of Analogous Pre/Post Assessment Tasks for MRSA Module in Spring, 2012

In order to inform the iterative design process of READI science modules, we developed assessments for the READI science modules (see Project READI Technical Report #16). The assessment model was designed to generate data about the cumulative impact of the READI science modules on student learning. Therefore the assessment tasks parallel the science reading-argumentation tasks in the READI modules but are reduced in scope and limited to individual work. The assessments are comprised of interrelated science reading/argumentation tasks: close reading with annotation of a set of science texts presenting information about a scientific phenomena, development of an explanatory mental model for the science phenomena synthesized from information presented in the text set, and, for the MRSA assessment, composition of a recommendation for potential courses of action drawing on their own mental model and grounded in evidence from the text set (see Science Attachments – Assessments). The assessment topic for MRSA was the spread of Malaria in Africa.

The Malaria assessment was administered as a pre- and post-module assessment in six classes in which the MRSA module was implemented. The school contexts for the classes and the level of implementation fidelity described above. As noted above, MF implemented the module for two weeks in four AP biology classes. They completed about one third of the module, from the beginning through the first intermediate multi-text modeling and argumentation tasks. AJ implemented the entire module in two physiology classes. Across these implemented classes, the assessments were administered one day before the class began the module and one day after they completed the module.

Results of Scoring and Coding of Assessment Sample

We developed a rubric to score the strength of students' models of the spread of malaria on three dimensions: identification of the elements involved (mosquitos, humans, bacteria), identification of interactions between the elements, and the aggregate effects of these. Project READI Technical Report #16 details the rubric and scoring approach. In Spring of 2012 we completed the analysis of the entire corpus of student data for MF and AJ. Below (Table 2) are the results that describe the findings for each class, by pre post, and for the matched students for whom we have both pre and post tests.

Table 2

	Elements			*Interactions*			*Aggregate Effects*
	A	*B*		*A*	*B*		
MF class (avg)	*3.14*	*2.97*		*2.76*	*3.23*		*1.33*
Pre	3.15	2.91		2.76	3.15		1.32
Post	3.14	3.03		2.75	3.31		1.33
AJ class (avg)	*2.88*	*2.39*		*2.43*	*2.54*		*1.23*
Pre	2.77	2.27		2.27	2.35		1.15
Post	2.97	2.50		2.57	2.70		1.30
Matched students only							
MF – two week implementation							
pre	3.15	2.91		2.76	3.15		1.32
post	3.09	3.03		2.76	3.32		1.35
Diff	**-.16**	**+.12**		**0**	**+.17**		**.03**
AJ – four week implementation							
pre	2.72	2.20		2.20	2.28		1.16
post	3.00	2.52		2.56	2.70		1.30
Diff	**+.28**	**+.32**		**+.36**	**+.42**		**+.14**

Based on this analysis, we saw larger gains in AJ's class on every dimension when compared to MF's class, though MF's students started out with higher scores in every dimension. When we focus on the data for the matched students (in blue above), there were slight increases in students' attention to Dimension 1B (Elements of the system: the role of the mosquito) and attention to Dimension 2B (Continuity and Transmission of plasmodium). There was a slight decrease in students' attention to Dimension 1A (Elements of the system: the role of the human) and very little change in students' attention to Dimension 3 (scale) for MF.

Like MF's students, the smallest gains were made in AJ's students' attention to scale (D3). On every other dimension, an increase between .28 and .42 was made on Dimensions 1A, 1B, and 2A and 2B.

AJ's students received a larger duration of the READI approach to science and literacy instruction as a result of the teacher's implementation of more of the module. In addition, AJ's implementation fidelity increased with ongoing coaching and experience during the module. These data seem to suggest that more time and experience with the close reading and modeling tasks of MRSA is potentially correlated with better student performance on the assessment. This data also suggests that implementing additional READI science modules may have increased impacts.

In addition to analyzing the malaria models students developed for the assessment task, we analyzed the annotations students made to the texts. Table 3 shows the pre and post mean values for each annotation code for the entire sample, comparing each code mean value for the classrooms combined.

Table 3. Mean Values for Pre-Post Test Annotation Analysis Across 2011 MRSA Unit-Malaria Assessment Sample

Student Annotation Type	Text	MEAN PRE TEST	MEAN POST TEST CODES
Total Number Marks	1	5.29	6.81
	2	9.43	8.82
	3	2.84	2.38
	4	0.69	1.11
Total Number of Comments	1	1.45	2.79
	2	1.75	2.94
	3	0.70	0.90
	4	0.62	0.72
Total Number Paired Marks and Comments	1	0.86	1.73
	2	1.04	1.88

	3	0.40	0.44
	4	0.40	0.51
Number Marks Associated with Text	1	5.37	6.73
	2	8.71	8.57
	3	2.40	2.17
	4	N/A	N/A
Number Comments Associated with Text	1	1.33	2.63
	2	1.55	2.92
	3	2.86	0.88
	4	N/A	N/A
Number Marks Associated with Visuals/Diagram	1	N/A	N/A
	2	N/A	N/A
	3	N/A	N/A
	4	0.67	1.13
Number Comments Associated with Visuals/Diagram	1	N/A	0.00
	2	N/A	0.00
	3	N/A	0.00
	4	0.62	0.70
Total Number Comments in Students' Voice	1	1.14	2.50
	2	1.41	2.84
	3	0.65	1.08
	4	0.74	0.74
Total Number Comments in Author's Voice	1	0.33	0.06
	2	0.35	0.14

3	0.09	0.00
4	0.12	0.00

On average, the students marked Text Two (see Attachments – Malaria Assessment) the most, both for pre and post tests, with 9.43 and 8.82 average markings respectively. We expected a higher number of annotations for this text, being a longer text than Text One (the next longest text) by four additional sentences. Next, in decreasing order and consistently across pre and post assessments were Text Two with 5.29 (Pre) and 6.81 (Post) marks; Text Three with 2.84 (Pre) and 2.38 (Post) markings; and, Text Four with 0.69 (pre) and 1.11 (Post) markings. Scoring also indicates that students increased their annotations on Texts One and Four after instruction in the MRSA module, reduced markings on Text Two slightly, and maintained about the same number of marks on Text Three.

In contrast, Comments increased consistently from pre to post assessment annotation for all students and for all texts. This is important since Comments more explicitly reveal student thinking in response to the text than do marks such as underlining or circling, which require much more inference to code. It also suggests that students were perhaps differently valuing their thinking alongside text in the context of the MRSA Module implementation which they had experienced.

The use of Paired Marks and Comments was the least used annotation strategy by students. Frequently, annotations on margins referred to ideas on the text, but only a portion of the sample used lines or brackets, arrows or a mark that was paired to the text and their comment. Students increased the use of this annotation strategy during post assessment annotation across all four texts. Text One increased from 0.86 to 1.73 average paired marks and comments; Text Two, from 1.04 to 1.88 average paired marks and comments; Text Three had the least change from pre to post with 0.4 average to 0.44 pairings; and Text Four increased from 0.40 to 0.51 average paired marks and comments.

On average, students made more marks than comments. The student annotations included many different types of markings, but the average for each text and across the sample had approximately 17-25% less comments than marks (e.g. Text One had 1.33 average comments as compared to 5.37 average marks). Text Four, the visual representation, was the least annotated text. We predicted that students' unfamiliarity with reading visual texts would result in lower annotations on such texts and believe this accounts for the relative paucity of annotations. Even so, the increase of marks and annotations on this text is evidence of some success in helping students view such science texts as requiring reading and comprehension.

Finally, student comments were coded for the degree of student voice found in the annotation. The data shows that students on average increased by 50% the use of their own voice with a 70% decrease in verbatim (author's voice) comments from pre to post assessment annotations in the expository texts (Texts One, Two and Three). For Text Four, the visual text, the mean number of student comments in students' own voice remained constant (0.74) and the mean number of verbatim comments decreased from 0.12 to 0.

Table four summarizes the annotations observed across the four texts for both of the implementing teachers, combined.

Table 4 Malaria Pre/Post annotation coding

Type	Pre – N = 28	Post – N = 29
Marks	Total 320	Total 503
Underlining, boxing, circling	258	361
Connecting	51	141
Symbols	13	14
Comments	Total 111	Total 253
Single Word	6	27
Phrase or Sentence*	105	226
Of these, some were:		
Marked as questions	9	89
Connected to marked text	58	181
Location of Comments		
Verbal text	108	233
Visual text	3	19
Voice of Comments		
Author (verbatim from text)	34	10
Student	78	240
Reading Processes*		
Summarizing	51	65
Making connections	6	33
Connections within text	12	30
Connections across texts	8	12
Inferencing, predicting	13	45
Asking inquiry questions	2	64
Science Reading Processes*		
Attending to science	0	7
Attending to elements/impacts	48	136
Attending to interactions	11	32

Generating a model	2	0
Generating a course of action	0	0
Supporting an assertion	0	0
Attending to cross-cutting concepts	0	1
Attending to scale	6	13

* Only phrases or sentences were coded for reading processes or science reading processes, since single word comments would require excessive levels of inference to assign codes describing mental processes.

The initial annotation coding thus reinforced our designs for module development, in which reading and literacy strategies are modeled for making sense of text and transforming text propositions into one's own voice. We hypothesized that such instruction will help students to build connections and queries with the text, increasing students' processing of information and thus, their metacognitive annotations. This is important in our development process, as teachers will also learn about which factors of annotation and modeling of reading strategies in the classroom might impact student learning the most. Also, for module development, the coding of assessments will help to highlight the importance of student voice in the science reading and comprehension processes.

Cycle Two: Implementation and Documentation of High School MRSA Module in 9th Grade Biology, Spring 2013 (see Curriculum Module Tech Report CM #27).

The high school MRSA module embodies the full sweep of READI learning objectives for science literacy that were articulated in 2012-2013 as reported in Technical Report Z. In Spring 2013, the co-design and implementation work with teachers and students produced further refinement and implementation of the high school MRSA module. The science design team worked with Chicago and California high school science teachers, MF and AJ, who had both implemented all or part of the MRSA module in spring of 2012, in preparation for implementing the module in April of 2013. AJ planned to implement MRSA beginning in early April. We consented students in preparation for documenting the implementation and scheduled administration of the revised Malaria pre-assessment prior to commencement of the MRSA module.

About four weeks ahead of the beginning of the unit, we interviewed AJ to get her ideas about the module, based on her work implementing the module in the prior year. This meeting was audio recorded. In this interview and planning meeting, AJ suggested several revisions to the module:

- Shorter – 15 days including pre post assessments
- AJ wants students to be able to leave the Interactive Notebook in the classroom so she can assess it incrementally, yet would also like to be able to send some of the

MRSA texts home for initial reading and annotation as homework, with completion of Evidence/ Interpretation note takers.

- All texts need very wide side and lower margins to accommodate practices already in place this year of making annotations alongside text margins and adding summaries of texts at the bottom of each page
- AJ requested a vocabulary journal in the Interactive Notebook students use throughout the module on the order of a personal dictionary – with room for visuals, parts of speech, and definition related to each word.
- AJ suggested we include more and briefer modeling of Evidence/Interpretation notetaking. AJ notes that students need her to model and them to subsequently practice Evidence and Interpretation from texts with Think Aloud. Students have trouble identifying particular evidences and more trouble noting precisely why they are important. A possible routine for supporting students discussed in the design meeting was having students highlighting possible evidence in the text for a discourse routine focused on sharing evidence and interpretation.

In discussion of how to make the model more efficient/shorter, together with AJ we considered:

- options for abridging the text set: reducing the number of texts, abridging some texts, making some reading homework. AJ plans to review the texts and provide suggestions.
- having some of the brainstorm/creative tasks be homework, keeping the hard tasks and conversations in the class.

AJ recommended having three reading to modeling cycles during the unit, with a final course of action recommendation and argument:

- Cycle 1 - transmission and infection
- Cycle 2 - spread (replacing sizing up MRSA which would now be an ongoing conversation strand and poster to record ideas)
- Cycle 2 – the staph –> MRSA evolution model
- Course of action and argument

Accordingly, we modified the text set and chose to separate the text set from the binder so that texts could be dropped in at different points. We also refined the inquiry probes and the unit's sequencing.

We also discussed how to reduce the logistical complexity entailed in developing and using multiple posters during the module but found that AJ sees instructional value in every poster and has a plan for handling them:

- Science thinking and talking - talk stem poster – high on the wall and in the IAN near students' personal reading strategies list
- Reading Strategies list (persistent – updated) – plus page in their IAN -across from talk stems
- Use white boards for temporary postering – take photos of these for research and classroom use.

To support AJ's review of the MRSA texts, we created a spreadsheet of the texts with word count and topics, as well as places for her to add her thoughts. In doing so, we noted a gap in the text set: nothing about how to slow down the evolution of antibiotic resistant staph bacteria. During the implementation of the MRSA module last spring, most student responses in AJ's class were directed at limiting infection, transmission and spread throughout the population. Very little aimed at the evolutionary aspect of the phenomena. In response, the team found an article on humans as evolutionary agents from the AAAS Science Magazine and excerpted a table from it that concerned MRSA. AJ will review this table for possible use as a last text before students argue for a course of action for slowing/ responding to the challenge of MRSA.

Analysis of Implementation/Design Research: Strengths and Needed Improvement

In Spring of 2013, researchers worked in a participant observer role with AJ, assisting with and documenting the MRSA unit implementation in a 9th grade Biology class. Twenty-six of the implementation lessons were audio and video recorded. One camera followed the teacher as she lectured and worked with small groups, another filmed the class and focal small groups during group work. Two observers attended each lesson and individually wrote detailed field notes and memos. We interviewed AJ after class as possible, and videotaped this as well. We gave students a binder of unit materials (Interactive Notebook) including texts and notetakers which they used for almost all classwork during the unit, and collected these for analysis. We collected other student work as well (scientific model posters created in small groups, post-its left on the models during peer review gallery walks). Finally, pre/post assessments on malaria were administered.

Goals for this iteration

With this iteration of the module we hoped to refine which texts should be taught together, and to provoke students to consider the biological evolution of the disease, rather than just its public health implications. AJ had additional goals that she worked on prior to the module as well as during its implementation. Prior to the module, AJ had deliberately had her students engaging in reading and annotation regularly. She wanted to extend the range of annotations they made while reading. In addition, she had been using evidence/interpretation journals all year, and with MRSA wanted to shift the students from gathering evidence in order to prove claims, to gathering evidence in order to make connections. She provided support for this shift in the form of a tagging process: students tagged each piece of evidence in the journals and then cross-referenced it to a conceptual "bucket" of evidence from different texts that could be connected. AJ had also designed a multiple-text modeling and argumentation unit about global climate change. Based on the models she observed students make, she wanted to shift students from thinking of models as purely visual, public service-style "pictures" to having them think of causal, scientific models.

Successes

In line with AJ's interest in moving students to focus on causal models, additional support was provided for peers giving feedback to one another on their MRSA models. Student materials were augmented to include a description of the purposes of peer review generally, epistemological questions addressed in peer review, a suggestion of the immediate benefit in this investigation of MRSA and that peer review is an effortful practice. During instruction, AJ offered examples of her own peer review processes, including questions she would ask herself as she reviewed a model. AJ was pleased with the results – the peer feedback displayed a level of disciplinary literacy that was much higher than prior to the implementation.

Challenges

Students began the module with limited stamina for engagement with text, despite having practiced annotation all year. Although we documented that students' stamina built over the course of the module, the level stamina students displayed at the end of the module was the level that had been needed at the beginning. We also noted that in order to develop explanatory models about the phenomena involved in MRSA infection, evolution, and spread, students required a certain breadth of disciplinary knowledge, and they were still developing the ability to build this knowledge through reading throughout the unit. We found that when students engaged in close reading, they did build this knowledge, but they didn't have the close reading skills early enough in the unit to access text-based knowledge from the beginning.

Additionally, the level of logistical management necessary to enact the MRSA unit presented a challenge, in part, because students were not accustomed to moving between whole class, individual, and small group activities in the service of completing complex tasks. AJ had to expend a lot of effort during these transitions to maintain the focus on the complex tasks students were attempting to engage with. We anticipate that when the module is used in a progression that has built students' experiences and stamina for close reading and reasoning, as well as fluency with these collaborative participation structures to support meaning making, students will be more facile in carrying out these cognitively complex activities. Accordingly, the logistical challenges will be minimized.

Another challenge, and one that constitutes a “next step” for us concerns the use of Evidence/ Interpretation journals. The journals are intended to be a support for gathering potential evidence for the inquiry questions. However, the students’ knowledge of what information may constitute evidence for a response to the inquiry changes, by design, over time as their knowledge and understanding of the phenomena builds. Much that ended up in the students’ journals was information but did not constitute evidence for a subsequent claim. In addition, information provided in the texts that could or should have been interpreted as evidence did not necessarily end up in the journals. We are working to understand how to best use the evidence and interpretation journals in the READI modules.

Results of Scoring and Coding of Assessment Sample

Previewing of the Malaria Pre-post Assessments from AJ’s 2013 9th grade class indicated increased frequency of nascent modeling in the annotations compared to the 2012 malaria pre-post assessments. We coded 17 matched pairs of pre-post assessments. The pre and post data included 305 comments of which 273 indicated close reading and 270 indicated close scientific reading.

From our preliminary analysis of student written annotations type 1 (number of annotation) and type 3 (student voice / author voice), we noted increased frequency of comments pre to post as well as increased frequency of comments in the student voice pre to post, suggesting student development through the MRSA module, along expected lines: more annotation and more annotation in own voice. See Figure 1 below.

In analyzing type 4 (close reading) annotations, we found the most frequently used annotation to be “paraphrasing and summarizing” (n=141), which appeared significantly more than all other types of close reading process annotations used by students to build meaning from the texts. The next most frequent type of annotation used by students was “asking questions with the intent to build knowledge” (n=41), followed by “predicting and inferring” (n=30). These annotations indicate growth in inquiry and meaning making processes we believe to be central to scientific reading. (See table 5 below.)

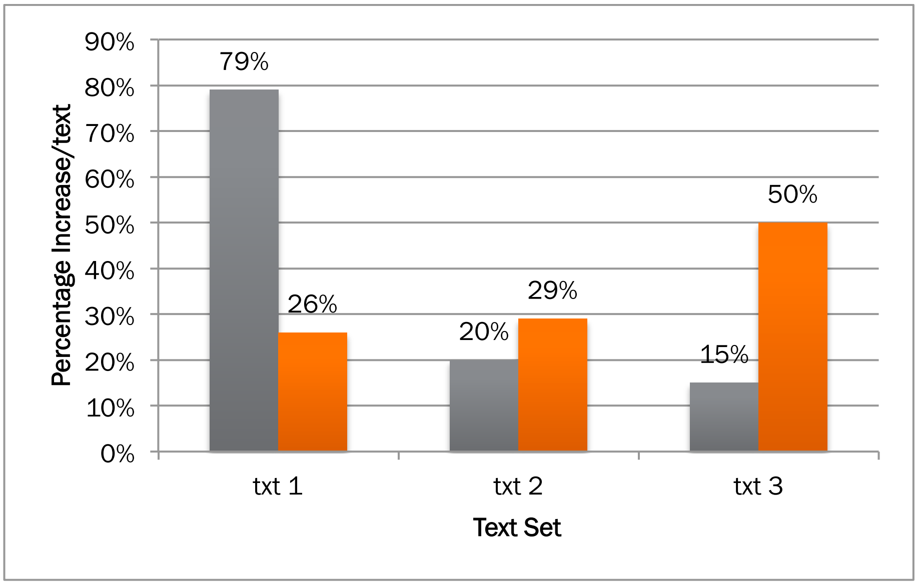

Figure 1: Percentage Variation Pre to Post in Student Annotations in comments (Blue) and comments in student voice (red).

Table 5: 2013 Sample of Malaria Pre-Post Annotations Analysis - High School MRSA Implementation in 9th Grade Biology Class (N= 17) Frequencies by Code and Text of Type 4 Codes: Comments Indicating Close Reading Processes

Text Set	Identifying Key vocab.	Identifying unknown vocab.	Attempt to define Unknown vocab.	Labeling	Identifying Main Idea of the Text	Paraphrasing & Summarizing	Identifies Familiar Concepts	Making Connections Own knowledge	Making Connections Within Text	Making Connections Text to Text (>1 text)	Predicting /Inference	Identifying/Expressing Confusions &/or Roadblocks	Using context clues to Build understanding	Inquiry Questioning for Knowledge Building	Other Close Reading processes
Text 1	0	2	2	1	1	64	1	2	1	2	6	1	1	13	0
Text 2	0	3	3	2	1	56	1	7	2	4	12	1	0	20	0
Text 3	0	1	1	8	1	21	1	3	6	2	12	0	0	8	0
Totals	**0**	**6**	**6**	**11**	**3**	**141**	**3**	**12**	**9**	**8**	**30**	**2**	**1**	**41**	**0**

Analysis of type 5 (Indicators of Scientific Reading Processes) resulted in the frequencies of types of annotations that were evident in our sample, which explicitly indicate the disciplinary practices of science (Table 6 below). Some of the students in this sample also showed evidence of systems thinking and nascent modeling in their annotations on the assessment texts. This is promising from the design standpoint, validating the module

development and approach to instruction to support precisely this kind of thinking with science texts.

Table 2

Text Set	Attending to Science in Text	Making Conceptual Change	Clarifying/Inquiring About Science in Text	Attending to the Phenomena (of Malaria)	Clarifying/Inquiring About the Phenomena	Attending to the Elements of the Explanatory Model	Clarifying/Inquiring About the Elements of the Explanatory Model	Attending to Relationships (links) in the Explanatory Model	Clarifying/Inquiring About the Relationships (links) in the Explanatory Model	Generating a Hypothetical/ Mental /Causal Model	Generate a course of action based on the explanatory model	Attending to the Scale, proportion and quantity of the system.	Identifying Conventions of a Science Text
Text 1	14	0	2	42	6	9	3	2	0	0	0	17	2
Text 2	13	1	0	9	5	14	7	29	17	10	1	0	0
Text 3	4	1	2	14	6	13	1	6	4	2	2	9	3
Totals	**31**	**2**	**4**	**65**	**17**	**36**	**11**	**37**	**21**	**12**	**3**	**26**	**5**

We conclude that the approach we have taken to develop text-based investigations in science has the promise to increase students' reading engagement and reading processes aligned to scientific purposes and practices.

Refinement of the High School MRSA Module

The MRSA module was positioned as the final READI module in the Efficacy Study intervention design for high school biology. As a result of development work for the Efficacy Study, the MRSA unit, intended to be enacted over the final five weeks of the intervention, now contains 13 texts and a 60-page interactive notebook. The module supports students in deepening their close reading and multiple-text synthesis for the purpose of constructing, justifying, and critiquing explanatory accounts for scientific phenomena.

Based on prior implementations and the instructional sequence designed for the Efficacy Study in high school biology, we changed the essential question for the module. Rather than considering the mechanics of the spread of a specific case of MRSA (e.g., how MRSA moves around a locker room), the essential question now focuses on considering MRSA in terms of epidemiology and evolution in a population, that is, how MRSA moves around the world. Some of the previously included instructional activities were also modified (seminar and peer review routines) to strengthen them. The text set was reordered to support the new learning progression and to better integrate the driving question into sense making prompts. The module shrunk from four parts to three, and from fifteen texts to thirteen, as we dropped the trailer for the movie Contagion and one account of an individual person's struggle with MRSA in order to better emphasize the epidemiological perspective over the personal. The concept of evolution came into play earlier and was given greater emphasis because of concerns that arose in observations of the module: students tended to focus on the public health implications of MRSA ("wash your hands!") instead of the driving question of the module – transmission and spread of MRSA throughout a population.

Finally, the teacher materials were also revised substantially to include a new cover page for the module describing the necessary pedagogies to support students through the module and to indicate how the module addressed both the Common Core State Standards and the Next Generation Science Standards. The teacher materials were designed as an educative curriculum, with hints for instruction, scaffolds and tools, and prompts to the teacher indicating when and how they might utilize these and other existing READI resources built into the lesson at the points they would most be needed.

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