Studying the Implementation of Text-Based Investigations on Water in Middle School Science Classrooms: Lessons from Collaborative Design-Based Research

Project READI Technical Report # 19

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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 Water module was the second text-based investigation module developed by the Project READI science design team, with input from RI, a sixth grade science teacher who planned to implement the unit. Prior to implementation, RI was largely unfamiliar with using and supporting students through text-based investigations. A district science coach and member of the READI science design team met with the teacher frequently as she attempted module implementation. The Chicago-based members of the team also met with the California-based members of the team to discuss and solve problems around the module implementation and clarify the intent of specific lessons and activities. Initial implementation of the Water module took place in April of 2012. Subsequently, the Water module was revised and implemented in these two middle school science classrooms with a cycle of refinement in between their enactments of the module. Students in both classes also completed a pre post assessment based on the Carbon Cycle. This technical report summarizes the lessons learned in these enactments and the refinements made to the text-based investigation based on these cycles of implementation research.

Design-Based Research Methods

Working in the tradition of design based research (e.g. Barab, 2006; Cobb et al., 2003), we worked closely with teachers to observe, discuss, and revise the curricular modules. As the Water 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.

Cycle One: Analysis of Implementation/Design Research: Strengths and Needed Improvement

During the course of documenting the module implementation it became clear that RI's instruction had not previously focused 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. Routines for discursive argumentation were missing, as were metacognitive routines for making student thinking public and assessable. In addition, expectations and accountability for student work seemed to be aimed very low in this middle school class.

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. 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. 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 text-based investigations in science.

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

Refining the Water Module Based on Implementation Documentation and Analysis

In the fall of 2012, the science design team made refinements to the Water module. New membership in this group consisted of new science design team members and two middle school science teachers serving as co-designers as implementer of the module, KM and RL. Based on evidence from the initial implementation of the water module, the team re-designed the unit with three primary goals in mind, including support for the development of: scientific close reading, scientific epistemology, and creating and justifying explanatory scientific models.

To accomplish this re-design, a sub-group of the team met several times to discuss evidence from the first implementation, generate refined hypotheses about needed additional supports to teachers and students, and a focused set of goals and learning outcomes for this module. By analyzing the text affordances and the order in which texts were presented in the unit and by attending to the iterative building of a model of the science under investigation, the team clarified the progression of modeling tasks students could engage in from close reading of the texts (see progression of causal models available from texts across the module, Appendix A). This progression, built from the texts selected and sequenced during the unit, in effect validated the causal model underlying the module design work and text selection.

These discussions led to a new version of the teacher guide for the water module, with more explanation and description of the goals, scaffolds and supports in the unit, as well as vignettes that describe exemplar moments of classroom discourse and the roles of teachers and students in these discursive events.

Following this work, the team convened with the two implementing teachers. Together, the group analyzed the texts and tasks in the unit, identified questions and concerns about the design, and generated ideas for additional supports for both teachers and students. The following day, design team members took all the teacher feedback, as well as observational data from working with the teachers, and re-organized the unit. The outcome of this work is a

redesigned unit with a stronger progression of reading, reasoning with evidence and claims, and modeling.

Cycle Two: Analysis of Implementation/Design Research: Strengths and Needed Improvement

Based on the planning and refinement of the Water module, the team prepared for implementation. As with the prior cycle, 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. Debriefing also often led to refinements to the module.

The Water Module was enacted first by RL, and then shortly after, by KM. The entire unit took 9 days in RL's class, and 8 days in KM's class.

RL's Implementation of the Water Module

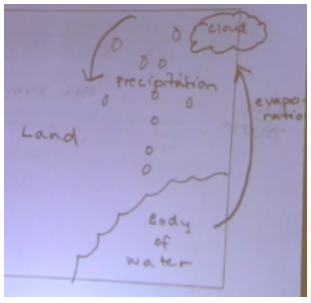
The water module was the first time that RL engaged her students in investigations that relied on engagement with texts alone, so much work was needed to establish classroom norms for close reading. RL began her enactment of the module in November 2012. Students had difficulty working extensively with each text – and engaging in close reading strategies in ways that would help students make progress on the essential questions guiding the module. In particular, RL identified that the students had difficulty making annotations or identifying evidence while working with texts in ways that were connected to the essential questions. Although the evidence and interpretation charts were useful to the teacher as a formative assessment tool to monitor students' understandings and misunderstandings of the textual evidence, the tool was less useful as a way to gather evidence and make interpretations of the texts in ways that help students develop explanatory models for the scientific phenomena. The facilitation of meaning-making discussions around these close reading strategies also proved to be difficult, as the teacher attempted to honor both the students' varying interpretations of the text, but simultaneously push students to make interpretations that were related the essential questions.

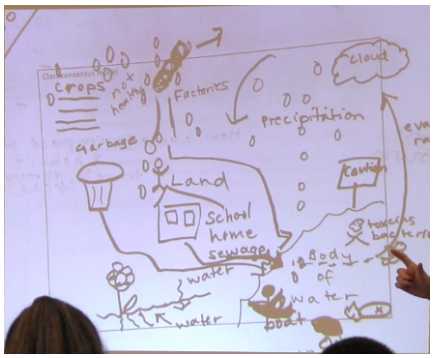
The facilitation of the meaning-making discussions was also often times dominated by students' prior conceptions about the scientific phenomena, which ran contrary to the evidence-based textual account that was central to the model-building work. In RL's class, students often times drew on their everyday knowledge of human impact on the water (e.g. people throwing garbage in the water), when asked to about how humans are impacting water. Although the textual evidence provides further specificity on this question (e.g. discussion of how point and non-point

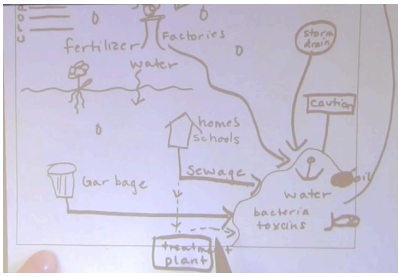
source pollutants enter the water and the subsequent effects on ecological systems), students relied primarily on their everyday understandings when completing the consequential tasks.

In addition to these reflections from RL, the science design team members also noted other challenges that arose during the enactment of the water module. Many of these observations are tied to (or an outcome of) the challenges that RL identified in her own reflections. The modeling tasks that were embedded throughout the module were often times disconnected to the investigations with the texts. Importantly, the modeling tasks were taken up as opportunities to illustrate the scientific phenomena, rather than providing a causal, explanatory account. Lack of attention to the causal mechanism, we conjecture, is related to students' take up of close reading strategies of attending to textual evidence and making interpretations in ways that related to the essential questions. Furthermore, there was a lack of scaffolding discussions that helped students attend to meta-modeling practices, such as discussions that helped students attend to what textual evidence was relevant or should be included in the model, attention to the specific representations placed in the model and what they symbolized, as well as opportunities and criteria for revising the model when additional evidence was obtained (See Figure 1 below).

Figure 1.

(a) 

→ (b) 

→ (c) 

Throughout the module, there were 3 opportunities for students to construct and modify their model of how humans impact water. The class consensus model became increasingly illustrative of how humans impact the water. Model (b) exemplifies this increasing complexity, where the water cycle processes of evaporation and precipitation are placed in the model alongside the various elements that impact the water quality – such as sewage and garbage that enter into water. There are elements of these models that come from students' prior knowledge, and the discussion supporting this model building consists primarily of the teacher eliciting students' ideas about what should be in the model, and the teacher subsequently placing this element in the model. Model (c) is a "cleaned up" version of model (b) that the teacher did, on the last day of the water unit. The only addition to model (b) that was made was the addition of a sewage treatment plant, which was the focus of a previous text on how water is treated. There was little

discussion regarding how this particular piece of textual information helps students develop a more robust explanatory account of how pollutants are entering into the water system.

Mid-Cycle Refinements to Improve the Water Investigation

Shortly after RL's enactment of the Water Module, the science design team members, including RL, met to reflect on the enactment of the water module. Through this work, several design features were identified as successful while others were identified as in need of further support. A subset of these challenges guided the modification of this unit prior to KM's enactment, while others were identified as issues to be discussed by the design team. In response to some of the challenges observed in RL's class, the following changes were made to the existing Water module prior to KM's enactment: Increasing opportunities to 1) develop meta-modeling knowledge, 2) synthesize information across texts, and 3) integrate textual evidence with prior conceptions. The following is a description of those changes.

1) To support the development of meta-modeling knowledge, we Introduced scaffolding conversations prior to each modeling task. This created opportunities for students to: synthesize what new textual evidence they had gathered, discuss what needed to be included in the model, why they needed to be included and how they would depicted, and return to the criteria laid out from the Reading Models module to help guide model-building process

2) To support cross-text synthesis, we built in explicit opportunities to make connections between texts. These discussions helped scaffold students by: making explicit what students have been gathering from multiple texts, helping students become aware of their own reading processes the first time they engaged with the text and how it was different the second time (affordances of returning to and working with texts multiple times), and providing opportunity for students to synthesize across texts – how reading multiple texts helped them make sense of a previous text differently, and more deeply

3) To support students in integrating textual evidence with prior conceptions, we added in multiple discussions that surfaced these alternative conceptions. In these discussions, students articulated the range of explanations, the teacher would guide the class in using evidence to sort through these alternatives, evaluating which was supported by textual information, and the teacher introduced several other texts (in the form of photographs) to supported students in evaluating in these alternative explanations and how they were different or similar to students' prior conceptions.

Finally, to support students' in constructing evidence-based argument, we scaffold the consequential task by providing an example of an intervention that would peripherally address

the causal model (during whole class discussion) and discussed its merit based on textual evidence.

KM's Implementation of the Water Module

KM enacted the modified Water module shortly after RL, beginning in January 2013. A subset of the new design features made a significant impact on the enactment in KM's class. Below, we document some of the differences in the two classes as a way to highlight the impact these scaffolds may have had on how students' engaged with modeling and changes in conceptions about the scientific phenomena.

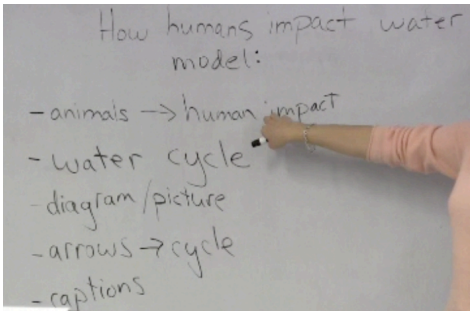
Grounding model construction in criteria and text-based inquiry

In KM's class, there were also multiple opportunities for modeling. Prior to engaging students in this modeling work, however, discussions guiding students to think about the relationship between the textual evidence and how these were to be represented in their model took place. The following is an excerpt of a discussion that occurred prior the modification of the ongoing model of how humans impact water. Notice in the excerpt below that the class refers back to the Reading Models unit (enacted prior to the Water unit) to highlight criteria for what models "help us do" and discussions that draw out the evidence from the text that elicits the need to update the students' current model. Lastly, the discussion ends with a continued need to gather more evidence from the text to add further specificity to this model. This situated the model-building work as tightly integrated to work with the text (T = teacher, Ss = multiple students).

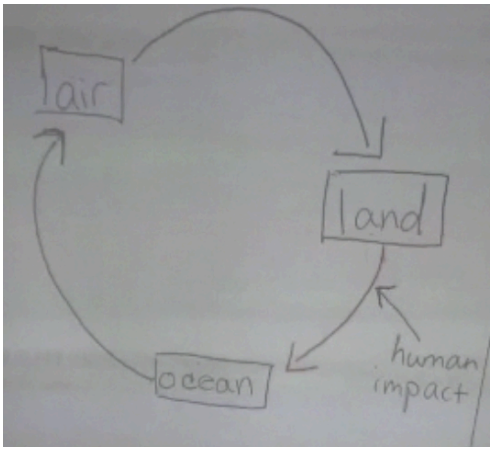
KM: 1/24/2013

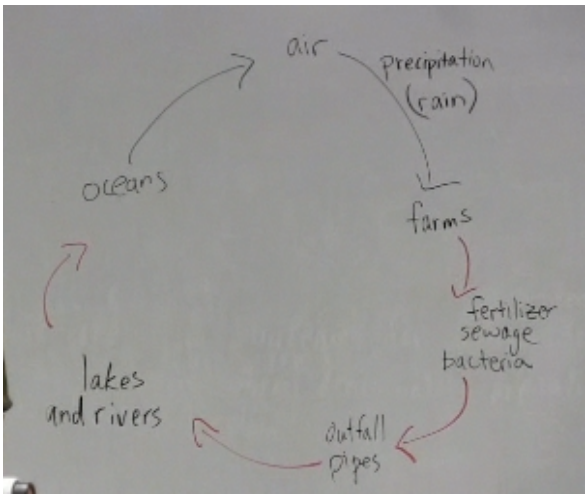
T: Based on what we know, we only looked at two texts. Let's think back: what makes a good scientific model?
S1: diagram
T: good. What does a diagram help you do?
S2: visualize
T: what else?
S3: helps me understand
T: Good *(writes this on top of page on the overhead)*
S4: caption
T: that's part of a model – what does it do?
S5: gives evidence
S6: they explain something
S3: predict

T: we want our model to explain…predict, understand. What did we learn about water on earth that we can put into our model so far? *(Teacher tells students to have the texts open along with their worksheet for revising their model)*
T: arrows….what does it show?
Ss: process…cycle, where the water goes
T: what else
S: groundwater
T: it has to hit the land
T: we know humans are impacting the water – at what point? *(Teacher points to the water cycle model, asking students where she should indicate human impact)*
S7; the land –
T: why
S7: that's where humans…put…that's where they live
T: is the water clean?
Ss: no
T: I'm going to put a red arrow… *(indicating the water as polluted)*
Ss: its dirty, untreated, human impact
T: we're going to come back to this model. We need to gather more evidence, and add more evidence of human impact



Snapshot of discussion prior to modeling work: connecting text-based evidence and identifying what needs to be included in the model

(a) 

→ (b) 

Example of model that was initially created and modified in KM's class. Model (b), which was created near the end of the Water module, has several features that are distinct when compared to RL's classroom. Aside from being more simplistic, there are two major elements of the model: where the water goes (the textual piece of the model) and arrows, which are both black and red. As students worked with more and more text, they were able to identify specific points in the model where humans were introducing pollutants into the water (indicated by the red arrows) and trace the outcomes this would have on the water cycle.

Supporting integration of prior knowledge, textual evidence, and synthesizing across texts:

In order to juxtapose the prior conceptions student had about human impact water alongside textual evidence, the teacher introduced two photos on the overhead at the start of the class period to help students sort through these candidate explanations. The excerpt below demonstrates how the teacher pushes students to make careful observations of the evidence from these photographs, connect it back to the texts they have been reading in the module, and their prior conceptions about how fertilizer and animal wastes were getting into the water ways:

> *(Teacher places a photo up on the overhead that is an example of how rainfall produces an overflow of water. Teacher begins the discussion by stating that they have been talking about human impact on the water and for them to look at these additional texts to help them)*
> T: what do you see happening…where do you think this was taken?
> S1: cropland…I see grass and weeds
> S2: I agree…in the background I see crops, tall grass
> …
> T: how is this connected [to our discussion yesterday about human impact on the water]–how is the water getting there?
> S3: I think its groundwater…you can't see where it comes from

T: what might farmers be doing, or naturally be happening?
S4: using fertilizers
S5: Ooooh!! When it rains that's how the water got to the crop
T: what could be in that water when it's raining?
S4: minerals…
T: S5 can you repeat
S5: when it rain the water flows into the stream
S6: Ohhhh
T: what could all be there?
S7: bacteria, human waste…
S4: fertilizer
T: what's being carried in that water?
Ss: Dirt
Ss: Fertilizer
[Discussion continues about whether or not the farmers are intentionally allowing fertilizer, etc. to enter into the water]
T: one more we're going to look at *(places another photo up on the overhead that shows overflow of water near a farm)*
S8: it has a farm next to a stream
T: very good. S9?
S9: I can see animals on the picture
T: there's a farm next to a stream, we have a picture of animals….
S10: I think this is a picture of waste and feedlot and it is in the "humans impact water" that feed lot and how it goes into the water,
T: How does it go into the water? (S10 expresses some hesitation, thinking that the teacher is critiquing his response) No you're okay -
S10: this is an exact picture of how humans are impacting water, and animal waste, animals by the stream
T: so how is the animal waste getting into the stream? Yesterday you guys said you all were saying [the farmers] were putting it down the drain? What's happening?
S4: over time they have to use the bathroom – they just go in the field…how is there animal waste going in the stream?
S11: it might rain, it could go into the stream
T: are humans impacting on purpose with their animals
S4: it depends if they have --

S5 : I agree with S4 cuz why would they let their animal go even by the steam so they could pollute the water

S2: I agree with you (talking to S5) and S4– the whole thing animals just poop everywhere and they know it rains

T: I hear you all saying is that sometimes, the animal waste or fertilizer….if the farmers keep their animals inside it won't happen as much…what else are they not carrying about?

S7: b/c they're animals, fertilizers, untreated sewage, etc.

Outcome of Supports: Student Responses on Consequential Tasks

In RL's class, the majority of student responses to the consequential task were based on prior knowledge, rather than on textual evidence. The task asked students to draw up a solution for human impact on the water, and the students in RL's class replied that humans needed to stop throwing garbage into the water. The scaffolds for integrating prior knowledge with textual evidence addressed this particular challenge in KM's class. A quick analysis of both the problem statement and the solutions generated to address human impact in KM's class reflected a change from what we saw in RL's classroom:

Totals for 30 Student responses, 7 blank responses (# in parentheses = number of Students with this type of answer):

Problem statement: How are humans impacting water?

- Humans are throwing stuff in the water: (3)
- Water is "dirty" (general statement): (4)
- Sewage, bacteria, fertilizer, etc. is getting into the water through runoff: (13)

Solution: What should be done?

- Tell people not to get in water: (3)
- General solution (i.e. keep the water clean): (6)
- Remove, sanitize fecal matter, separate rain and sewage pipes, or keep fecal matter from entering the water: (12)

Thus, multiple design cycles and observations during teacher implementation of the Water Module, coupled with cycles of reflection and analysis, enabled us to quickly refine and improve the module and teachers' understanding of the pedagogical goals and imperatives for text-based investigations to support reading for understanding and argumentation in science. The result was more robust evidence of teacher uptake and student learning opportunities and enactment of the module closer to the design goals of the project. Student responses on consequential tasks associated with the module were also closer to the mark.

See READI Curriculum Module Technical Report CM #25 Earth Science: How are Humans Impacting Water, Spring 2012 for Iteration 1 of the Water Cycle, READI Curriculum Module Technical Report CM #26 Earth Science: How are Humans Impacting Water, Spring 2013 for Iteration 2.

Carbon Pre Posts

During the implementation of the Water unit, students completed a pre post assessment in which they were asked to read and use multiple representations to construct an explanatory model of how humans impact the Carbon Cycle.

Our analysis from these pre posts indicates some changes both in how students use multiple texts during this task, and that these differences are consequential to the strength of the models they build. We found a small pre/post shift from single to multiple text use for those students who made use of the texts. Those who used a single text to construct their model often relied on illustrations vs. written text. Multi-text users were more likely to use all aspects of a text – both illustrations and running text. Finally, those who used multiple texts included more elements and links in their models. Thus, our findings suggest that the unique ways that multiple text users engaged with the texts, particularly their engagement with all aspects of the texts and synthesis within and across texts, led to the creation of high quality models that reflect a complete, integrated understanding of the phenomenon. These findings were presented at the International Conference of the Learning Sciences (James, Goldman, Ko, Greenleaf & Brown, 2014)

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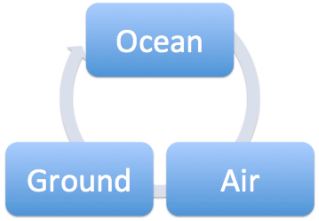
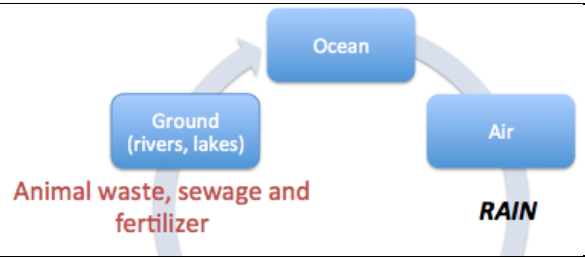
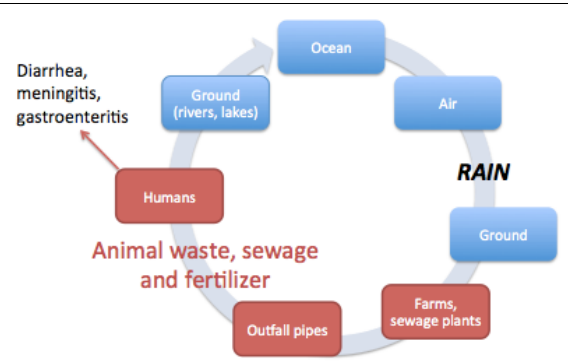
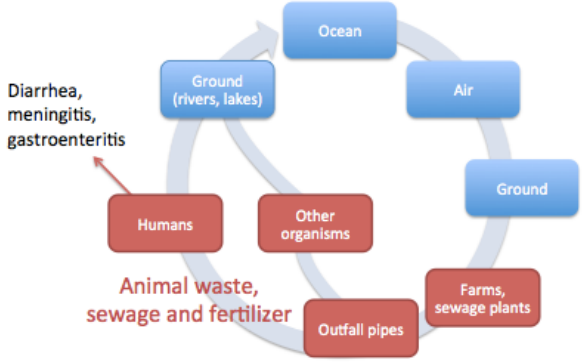
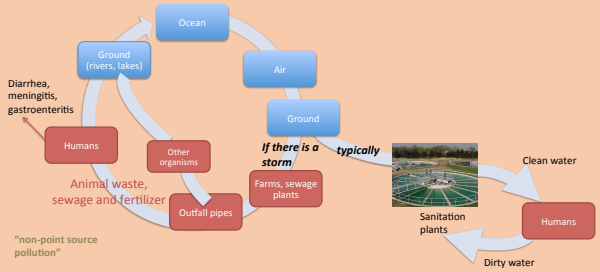
James, K., Goldman, S.R., Ko, M, Greenleaf, C.L., Brown, W. (2014). Multiple-Text Processing in Text-Based Scientific Inquiry. Polman, J. L., Kyza, E. A., O'Neill, D. K., Tabak, I., Penuel, W. R., Jurow, A. S., O'Connor, K., Lee, T., and D'Amico, L. (Eds.). (2014). *Learning and becoming in practice: The International Conference of the Learning Sciences (ICLS) 2014, Volume 3, pg. 1571-1572.* Boulder, CO: International Society of the Learning Sciences.

Appendix A. Progression of Causal Models Available from Texts Across Module

Question	Texts that support	Content learning	Supporting model	Problematizing Qs
What path does a water molecule take? (1)	Model of water cycle (USGS)	Water goes from the ocean, into the air, back onto land		In what ways do you think humans impact this cycle?
How do humans impact the water cycle?	1) Model of human impact, 2) "what's in third creek?"	Humans introduce sewage, fertilizer into the ground water		How does the sewage and fertilizer get into the water?
How does sewage and fertilizer get into the water?	"What's in the Chicago river?"	Sewage combines with rain water and flow into the river through outfall pipes		Let's start thinking about how water molecules travel through the water cycle

What path does a water molecule take? (2)	1) "what's in your lemonade", 2) Model of human impact	Storm water carries fertilizer and wastes into the river		How does this process impact my family, my community and me?
How does this process impact me?	"No Day at the Beach"	Raw sewage can lead to disease (sore throats, diarrhea, meningitis, gastroenteritis and illnesses)		Does this process impact other living organisms (like the ones that live in water)
How does this process impact other organisms? Does everyone have clean water?	1) "Who needs water?" *(Discussion),* 2) Our basic water needs, 3) Goldfish bowl, 4) water and sanitation	We need water for drinking, cooking and cleaning; 1 in 6 do not have access to clean water, diarrhea causes death because there is not safe and clean water. Water also affects other organisms (esp. those that live in water)		What is the process of cleaning water so that it can be consumed? *(how can we get cleaner water?)*
How does water	1) Where	Pipes carry the water from	*** great time to compare the model Ss are*	How can we better

get 'clean'?	does the water we use come from? Where does it go? 2) the water cycle 3) Where does run off go?	lake to treatment plant, and the treatment makes the water safe to drink. It is stored in reservoirs until you turn your faucet on	*building with the one that's provided in the text, ask questions like what does it have that we don't' currently have, why that component is helpful to our understanding, etc.* Helpful questions may be: what does this model depict (vs. ours)? How can we use this information and add to ours?  	protect people from getting sick? ← this should be the consensus model
How do we use what we know to keep the water clean?	1) Our polluted beaches, 2) water cycle 3) article on cleaning process (page 40)	Identify points in the pathways where we can prevent humans from getting sick	Students need to make sure they use the model as the basis for their recommendation about how to keep the water clean – point to specific parts of the cycle, reason about why this would help keep water clean, and what evidence they have that supports that from the reading	