Research-Based, Standards-Aligned Instruction: IQWST Middle School Science Curriculum

LeeAnn M. Sutherland and Deborah Peek Brown
The University of Michigan

IQWST (Investigating our World Through Science and Technology) is a comprehensive, 12-unit middle school science curriculum (Krajcik, Reiser, Sutherland & Fortus, 2011) designed such that the four content strands—physics, chemistry, life science, and Earth science—are addressed each year in grades 6-8. Units are sequenced for coherence, layered to build understanding of core ideas and facility with scientific practices across the middle school years. Although IQWST was developed with NSF support that began in 2001, years before the Framework/NGSS and the Common Core (CCSS), it was designed by science and literacy educators applying the latest research as to how students learn. Thus, it stands to reason that a dozen years later, IQWST aligns conceptually with both NGSS and CCSS. Rather than define lesson learning goals as discrete pieces of content that students memorize, IQWST developers crafted *learning performances* that combine content with a scientific practice—clarifying not only what students should know but also what they should be able to do with their content understanding. This conceptualization of learning performances jibes with NGSS' *performance expectations*, which blend a disciplinary core idea (content), a crosscutting concept (content), and Scientific Practice(s). The act of combining content with practice makes IQWST an exemplar of research-based, standards-aligned instruction, as it is primarily through employing scientific practices that IQWST simultaneously addresses NGSS and CCSS.

A number of foundational design principles undergird IQWST. Most apropos to CCSS requirements and to NGSS Practice #8: Obtaining, Evaluating, and Communicating Information are three interrelated principles. First, the principle of coherence. Science content and practices are addressed in a manner such that each new lesson, new unit, and new year of middle school supports deeper and broader understanding of disciplinary core content and increasingly sophisticated use of scientific practices. Second, scientific practices and literacy practices are integrated; that is, students *do* science, as well as read, write, and talk science in every lesson. Third, as they investigate phenomena, students construct models and develop explanations of the *how* and *why* of science, and they engage in evidence-based argumentation as to the credibility of competing explanations. Students address reading, writing, speaking and listening, and language standards throughout their middle school experience and on a daily basis. This continual revisiting of concepts and practices, each time developing greater facility with practices and deeper understanding of concepts, distinguishes IQWST from modular curricula (stand-alone units). In IQWST, student learning is scaffolded via lessons sequences that build understanding across time.

While pedagogy does not play a role in either NGSS or the Common Core, as both sets of standards enable teachers to determine how to address the standards in their classrooms, pedagogical support is central to IQWST. Research illustrates, for example, that strategies approaches are inadequate to support users' long-term learning. That is, even when students learn a strategy for reading or writing in a particular context—a reading-comprehension strategy in their ELA classroom, for example—they do not apply (transfer) that strategy to other contexts (use it in Science class). IQWST's approach to teaching students how to write explanations or to engage in argument from evidence, then, is not approached as a "strategy" but as the crux of how scientists obtain, evaluate, and communicate information. The concept that your ideas (eventually *claims*) must be supported with evidence, and that a listener or reader needs to understand how you arrived at your conclusion (to follow your reasoning) is approached as a way of thinking about the world of communication, not as a "strategy" for communicating. So, while a claim/ evidence/reasoning approach can be turned into an algorithmic, fill-in-the-blank exercise, the intent is that the CER framework serves as a scaffold to support students as they come to understand what effective communication looks like in science. Integrating the Common Core reading, writing, and speaking and listening standards with NGSS Practice #8 is the very heart of IQWST pedagogy. More specifically:

A) In every lesson in every unit, students investigate phenomena; they *do* science. In addition, they read, write, and talk science—engaging in multiple forms of scientific discourse and communication, integrated such that each informs and reinforces the others.
B) The texts that comprise the student reading materials (predominately expository text), and the teacher edition guidelines to support teachers in introducing and following up at-home reading, incorporate what is known about reading comprehension (engaging the reader, eliciting prior knowledge, and setting a purpose for reading) (Sutherland, 2008).
C) As they explain the *how* and *why* of science, or engage in argument from evidence, students must obtain information from in-class activities and from reading, must evaluate and integrate the two, and must communicate their understanding to their peers in both oral and written form, sometimes individually and sometimes collaboratively.

Integration of NGSS and CCSS is the hallmark of IQWST. Both literacy practices and scientific practices are supported in the context of learning science, of "making sense" of core science ideas and concepts. Students read expository text closely, making inferences, and citing text to support conclusions they draw either in written responses to embedded questions, in in-class discussion, or in crafting explanations and arguments that draw on readings and investigations as evidence for their claims (Reading: Key Ideas and Details). The "texts" students encounter include those provided to support their learning as well as their own original texts (explanations and arguments that they and their peers develop). Students engage in an ongoing process of assessing how purpose shapes the content and style of a text (which details are chosen to support a particular position), and how specific word choices (especially science vocabulary) shape meaning (Reading: Craft & Structure). They also must integrate content from first-hand investigations and from text, and from words and graphic representations (Reading: Integration of Knowledge and Ideas) as they learn. They write arguments to support claims, using valid reasoning and relevant and sufficient evidence. Students must select and analyze content, and then write to convey complex ideas (Writing: Text Types and Purposes), demonstrating their understanding of the subject (Writing: Research to Build and Present Knowledge) in a manner whose organization and style are appropriate to the task, purpose, and audience (Writing: Production and Distribution of Writing). As peers listen to and read one another's explanations and arguments in a cycle that parallels ELA process writing, they evaluate one another's texts—claims made, validity of the reasoning, and relevance and sufficiency of the evidence (Reading: Integration of Knowledge and Ideas).

In addition, IQWST reading materials tie closely to what was done in class. Readings are designed to be homework. They support in-class investigation and discussion but reading is not, itself, an in-class activity. Thus, as students obtain, evaluate, and communicate information, they do so via a range of types of reading and levels of text complexity called for in the Common Core, reading and comprehending complex informational texts independently and proficiently. They also address a range of writing tasks: writing to answer embedded questions in the texts they read, to pose and answer questions of their own, to draw conclusions from investigations they undertake, to provide rationale for their predictions, to compare predictions with outcomes of investigations, and to complete other writing tasks of shorter duration. Explanations and arguments require additional time for reflection and revision. Students write "routinely over extended time frames … and shorter time frames."

IQWST students also have multiple, ongoing opportunities to address all six speaking and listening standards, as well as the six language standards identified in the Common Core. Students engage in discussion in every class period, using domain-specific vocabulary and the conventions of standard English as they "participate in a range of conversations … building on others' ideas and expressing their own clearly and persuasively." They are called upon not only to "present information, findings, and supporting evidence such that listeners can follow the line of reasoning" wherein "the organization, development, and style are appropriate to task, purpose, and audience," but also to "evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric" and to provide feedback.

Field tested in urban, suburban, and rural schools across the U.S., IQWST is notable for actively engaging diverse students in all aspects of the scientific enterprise. Driving Questions provide a structure

around which activities are organized. In every lesson, students investigate a sub-question that enables them to move closer to answering the driving question. In a chemistry unit that addresses the particle nature of matter and phase changes, "How do I make new stuff from old stuff," students investigate a variety of materials, and learn that everything on Earth is made from a small number of elements, and each of those elements is made of one type of atom. Pure substances are made up of one type of atom or molecule, and when particular substances combine in particular ways, a chemical reaction takes place that involves energy and results in the substances becoming one or more new substances, with new properties.

Along with the in-class investigation of various substances, which culminates in combining a fat with sodium hydroxide to make their own soap, students read other examples of substances and mixtures in their everyday worlds, and of chemical reactions in their everyday experience. One reading is about Cubic Zirconium and diamond—two materials that look alike but are very different. To prepare students for independent reading, a teacher might ask, "What if someone wanted to sell you diamond earrings, but you weren't sure if they were really diamond? How could you figure it out?" After students share ideas, they read for homework. They learn generalizable principles about properties of substances in class, through investigation, but they encounter more information, including data about the melting points, solubility, and density of CZ and diamond from their reading.

Students make comparisons by interpreting a data table and reading text about both materials. The readings reinforce the in-class activities. (In a format often like: Today you investigated X, and through that activity you learned Y, and raised new question Z.) Readings then extend in-class activities by requiring students to apply what they are learning to a new context they are likely to have experienced or with which they are likely familiar. A sample task is found in this excerpt from their reading.

Constructing a Scientific Argument

In this section, you will practice constructing an argument by looking at data from two rings. Here are two rings that look very similar. The stones in the rings look the same. They are the same size. Both rings occupy the same volume.

The following table summarizes some properties of the stones in each ring. The table gives you data you need to compare the stones. Decide whether they are the same or different substances. Your argument needs a claim, evidence, and reasoning that shows how the data you choose connects with the claim you make. Your reasoning will need to include scientific principles about substances and properties.

	Properties				
	Density	Color	Hardness	Melting Point	Solubility in Water
Stones in Ring #1	5.92g/cm³	No color	8.5	2759°C	No
Stones in Ring #2	3.52g/cm³	No color	10.0	3547°C	No

This type of example occurs throughout IQWST—students obtain information from text and from in-class activities, then integrate the two as each reinforces the other, and as students investigate, discuss, read, discuss, write, discuss, and revise. In a life science unit, students explore changes in the trout population in the Great Lakes, read about pesticides and pollution, read about the introduction of an invasive species (sea lamprey), and further investigate by dissecting both types of fish. They evaluate information obtained in print and through investigation, and argue the cause of the decline in the trout population as represented in a graph they analyze and interpret. Is it the overuse of pesticides that pollute the waters? Is it the accidental introduction of the sea lamprey into the ecosystem? Is it the fact that one species' likelihood of reproducing in large numbers is greater than the other's? Is it one of these explanations, or a combination of factors? What combination? How would one know? What difference does determining the answer make for finding a solution to the problem? These types of questions require data analysis and interpretation, integration of information gleaned from various sources, crafting of an argument using evidence from print and from investigation, presenting an argument to peers, and revising based on feedback. This integration of science and literacy—especially as needed to engage in scientific practices—makes IQWST an exemplar of how NGSS and CCSS can look in tandem.