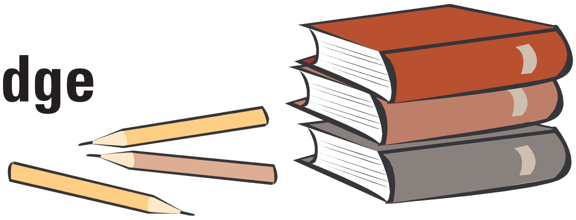
INQUIRY LEARNING

Teaching and Assessing Knowledge Integration in Science



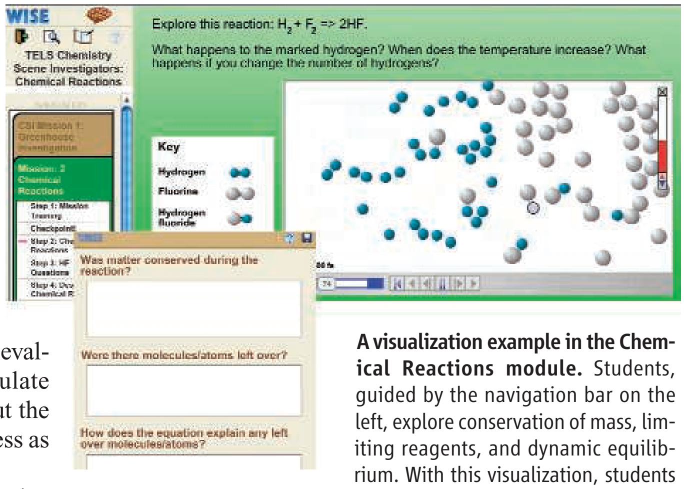
Marcia C. Linn,[1]* Hee-Sun Lee,[2] Robert Tinker,[3] Freda Husic,[1] Jennifer L. Chiu[1]

Interactive visualizations combined with online inquiry and embedded assessments can deepen student understanding of complex ideas in science.

Students grapple with multiple, conflicting, and often confusing ideas while they learn scientific concepts. Research has shown that instruction is both effective and durable when teachers use students' ideas as a starting point and guide the learners as they articulate their repertoire of ideas, add new ideas including visualizations, sort out these ideas in a variety of contexts, make connections among ideas at multiple levels of analysis, develop ever more nuanced criteria for evaluating ideas, and regularly reformulate increasingly interconnected views about the phenomena (*1*, *2*). We refer to this process as knowledge integration.

Common testing procedures emphasize recall of scientific information over deep understanding of science reasoning (*3*), and as a result, teachers focus most of their time on "covering" the many required topics. This approach leaves teachers with little time to help students integrate their ideas (*4*) or engage in scientific inquiry as mandated by national standards (*5*, *6*) and leaves students with isolated ideas, little understanding of science reasoning, and a perception that science is not relevant to everyday life (*7*).

The Technology-Enhanced Learning in Science (TELS) Center has developed interactive lessons that improve inquiry learning by strengthening knowledge integration and taking advantage of visualization technologies in both instruction and assessment. TELS designs visualizations of scientific phenomena (*8*) and embeds them in instructional modules (see figure, above) to help students integrate their ideas (*9*, *10*). The TELS Center created two modules each for the science courses most common in middle school (life, physical, and earth sciences) and high school (biology, chemistry, and physics). Topics selected were those from the science standards that teachers say are most challenging. TELS designed assessments to measure knowledge integration about the module topics.



A visualization example in the Chemical Reactions module. Students, guided by the navigation bar on the left, explore conservation of mass, limiting reagents, and dynamic equilibrium. With this visualization, students examine the effects of heat and number of molecules on chemical reactions and explain their ideas in embedded notes shown on the left (*21*).

Participants and Design

TELS studied two time-delayed cohorts of students. We recruited teachers in 16 schools across five states and assessed the performance of their students at the end of one school year after they studied the typical curriculum (3712 Typical Cohort students) using TELS assessments in six courses. The next year, we offered teachers at these schools one or two 5-day TELS modules to use instead of their previous treatment of comparable content. We tested the performance of new students in the same schools who had the opportunity to study TELS (4520 TELS Cohort students) at the end of the second school year, using a subset of the items from the first year that aligned with TELS modules as well as new items that served as a baseline for future modules. We used this assessment sample of 8232 sixth- to twelfth-grade students to analyze item properties of multiple choice and explanation items in both years of TELS assessments. Twenty-six of the 43 teachers participated in both Typical and TELS Cohort assessments and taught one or two TELS modules in the subject area of the assessment. We used this comparison sample of 4328 students to analyze the overall impact of TELS modules and the impact of TELS by science course and teacher.

TELS Modules

Designed by partnerships of discipline experts, learning researchers, classroom teachers, and technology specialists using the Web-based Inquiry Science Environment (WISE), TELS modules guide students in research-based knowledge integration practices using an online map and embedded assessments (*11*, *12*). TELS modules make science visible by representing unseen phenomena such as molecular reactions (*13*). They showcase the relevance of science with current scientific dilemmas such as choosing among treatment options for cancer, interpreting claims about global warming, or selecting an energy-efficient car. One life science module connects the design of a cancer medication to a visualization of the stages of mitosis. A physics module allows students to experiment with variables governing deployment of airbags. Teachers can access student ideas online in real time and use them to tailor instruction.

The TELS high school chemical reactions module uses an interactive visualization (see figure, above) to help students explore factors influencing greenhouse gases. The inquiry map guides students to articulate their ideas, test their predictions, critique each other's views, and distinguish new and elicited ideas. Typical chemistry students have difficulty connecting symbolic and visual representations of reactions and often fail to account for conservation of mass and the effects of heat and temperature. Static representations in textbooks lead some chemistry students to report that molecules are malleable or colored and to argue that molecules stop moving after they react (*14*, *15*). The TELS chemical reactions module helps

[1]Graduate School of Education, University of California, Berkeley, CA 94720, USA. [2]Department of Education, Tufts University, Medford, MA 02155, USA. [3]Concord Consortium, Concord, MA 01742, USA.

*Author for correspondence. E-mail: mclinn@berkeley.edu