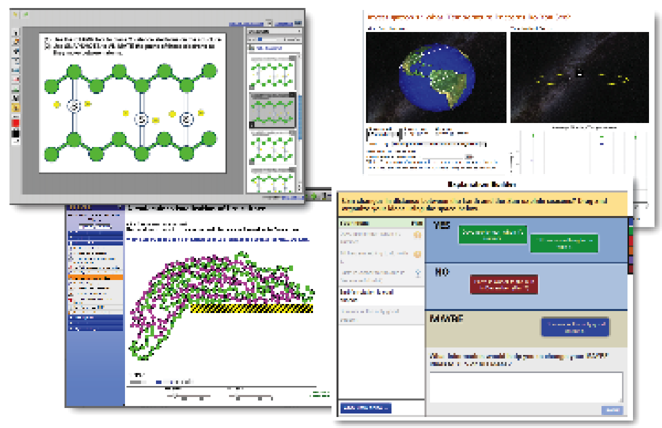
The Web-based Inquiry Science Environment (WISE)

Free and open source platform for **science inquiry** teaching and learning

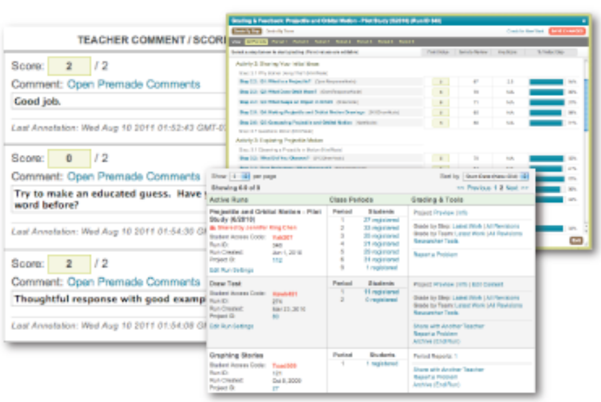
http://wise.berkeley.edu

WISE is a powerful, research-based online platform for designing, developing, and implementing science inquiry activities. Since 1997, WISE has served a growing community of more than 15,000 science teachers, researchers, and curriculum designers, as well as over 100,000 K-12 students around the world.



Inquiry Learning

In WISE units students collaborate to investigate socially important questions such as climate change. WISE makes complex concepts including chemical reactions, photosynthesis, plate tectonics, and thermodynamics visible using powerful visualizations. Units are designed following the knowledge integration framework.

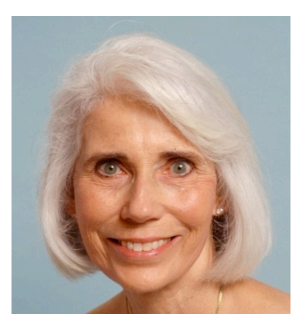


Key Features & Benefits

- **Library of Free, Classroom-Tested Projects**
- **Assessments Aligned with Instruction**
- **Interactive Visualizations & Simulations**
- **Embedded Prompts for Reflection & Collaboration**
- **Instructional Support for Diverse Learners**
- **Teacher Feedback & Guidance Tools**
- **Powerful Authoring & Customization Tools**

Research Based, Classroom Tested

WISE curricula and software are developed by the **Technology Enhanced Learning in Science (TELS) Community** – a consortium of teachers, educational researchers, scientists, and technology experts. WISE is supported by generous grants from the **National Science Foundation** (http://nsf.gov). Visit http://telscenter.org for more information.



Director Marcia C. Linn

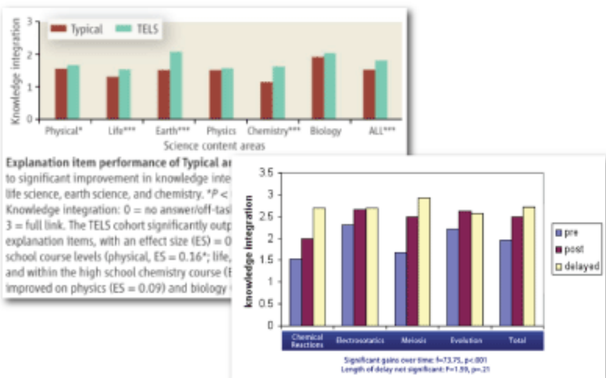
University of California, Berkeley

TELS TECHNOLOGY ENHANCED LEARNING IN SCIENCE

Impact of WISE Curricula

Knowledge Integration

Students grapple with multiple, conflicting, and confusing ideas about science. WISE curriculum and technology design follows the **Knowledge Integration** framework to support students in articulating their repertoire of ideas, adding new ideas, sorting out their ideas in a variety of contexts, and making connections at multiple levels of analysis. WISE helps students formulate a nuaunced and coherent understanding of scientific phenomena.



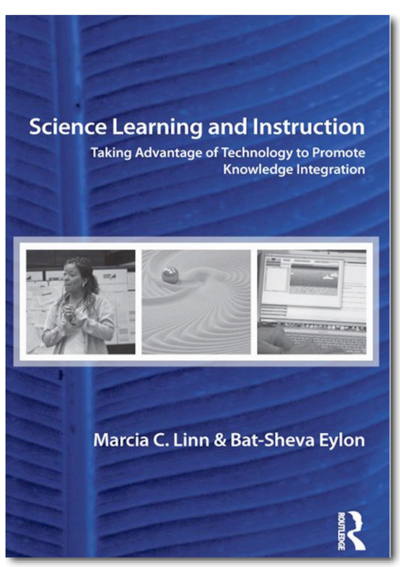
Proven Learning Gains

WISE curricula have been tested in middle and high school classrooms for over two decades in more than ten school districts. Research shows that WISE curriculum units improve student learning of difficult standards-based science topics and that students continue to integrate their ideas and strengthen their understanding even after the units have been completed. For more information about WISE learning results, visit http://telscenter.org/publications.

Journal Articles

- Linn, M.C., Lee, H.-S., Tinker, R., Husic, F., & Chiu, J.L. (2006). Teaching and Assessing Knowledge Integration in Science. Science, 313, 1049-1050.
- Gerard, L. F., Varma, K., Corliss, S. C., & Linn, M. C. (2011). A review of the literature on professional development in technology-enhanced inquiry science. Review of Educational Research, 81(3), 408-448.
- Lee, H.-S., Linn, M. C., Varma, K., & Liu, O. L. (2010). How do technology-enhanced inquiry science units impact classroom learning? Journal of Research in Science Teaching. 47(1), 71-90.

Books



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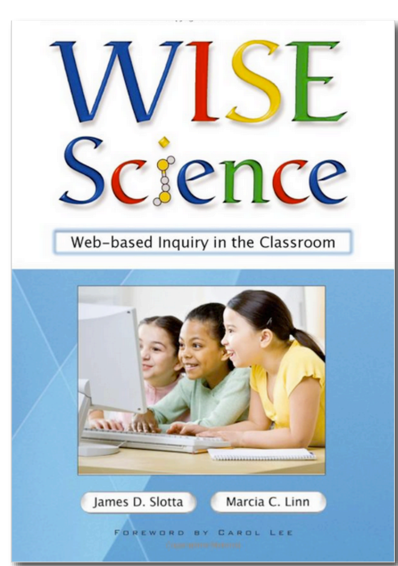

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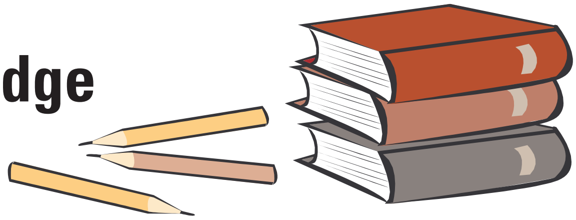
INQUIRY LEARNING

Teaching and Assessing Knowledge Integration in Science



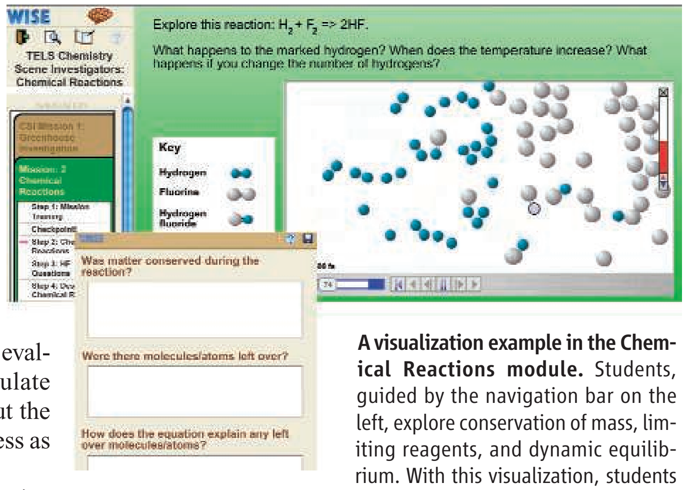
Marcia C. Linn,[1]* Hee-Sun Lee,[2] Robert Tinker,[3] Freda Husic,[1] Jennifer L. Chiu[1]

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

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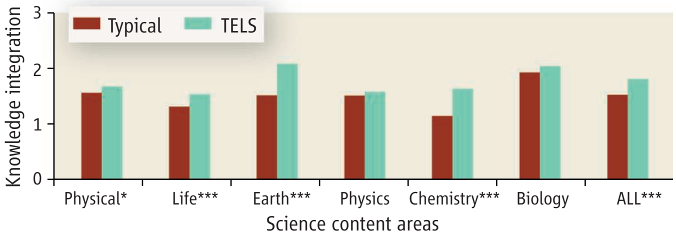
students sort out these ideas using an interactive visualization with which students can gather evidence about limiting reagents and study the relationship between molecular behavior and temperature by modifying inputs such as temperature or proportions of reactants (*16*). TELS modules help students act like scientists, comparing viewpoints, generating criteria for selecting fruitful ideas, fitting ideas together in arguments, gathering evidence for their own views, and critiquing the arguments generated by their peers.



Explanation item performance of Typical and TELS Cohorts. TELS modules led to significant improvement in knowledge integration scores for physical science, life science, earth science, and chemistry. *$P < 0.05$, **$P < 0.01$, and ***$P < 0.001$. Knowledge integration: 0 = no answer/off-task, 1 = no link, 2 = partial link, and 3 = full link. The TELS cohort significantly outperformed the Typical Cohort on the explanation items, with an effect size (ES) = 0.32***, as well as within all middle school course levels (physical, ES = 0.16*; life, ES = 0.35***; earth, ES = 0.64***) and within the high school chemistry course (ES = 0.81***). Students moderately improved on physics (ES = 0.09) and biology (ES = 0.11).

TELS Assessments and Scoring

To measure inquiry skills as defined by the science standards, TELS created assessments composed of multiple-choice and explanation items that asked students to connect ideas in arguments. TELS researchers created tests for each of the six courses that include items from our research as well as items published by national, international, and state assessments. We scored all of the multiple-choice items dichotomously. We used the TELS knowledge integration rubric to capture progressively more sophisticated levels of reasoning on explanation items (*16*).

We analyzed the properties of all 201 items administered to the assessment sample (*16*). We found that the items were highly correlated and that 97.5% measured the same dimension of learning. In addition, higher scores in each explanation item were obtained by students who were estimated to have higher knowledge integration abilities.

Overall, 98% of the 83 explanation items scored with knowledge integration rubrics were highly capable of discriminating respondents with high knowledge integration abilities from those with low knowledge integration abilities. Only 16% of the 118 multiple-choice items showed similar discrimination. Of multiple-choice items, 39% did not have acceptable discrimination indices (*16*).

Student Performance

The 26 teachers in the cohort comparison study spent between 2 and 10 days implementing the TELS modules. A few teachers had to shorten their lessons due to school scheduling, but 31% completed two modules.

To determine the impact of TELS, we used 50 items that were administered to both cohorts and aligned with the modules. Overall, for the multiple-choice items, TELS had no impact (Typical mean = 55.0% correct; TELS mean = 54.8% correct; effect size = 0.007). For the explanation items, TELS resulted in improvement equal to more than a quarter of a standard deviation (Typical mean = 1.52; TELS mean = 1.78, effect size = 0.32, $P < 0.001$). As expected, because the explanation items are better able to discriminate levels of knowledge integration, they showed more sensitivity to instruction. We analyzed TELS, teacher, and science-course effects and found significant effects for TELS and teacher (*16*). Improvement was similar across science courses and individual comparisons were significant for four of the six courses (see figure, above).

Teachers varied in their access to technology, experience with inquiry, prior knowledge of their students, and experience with technology, all of which could contribute to the teacher effect. We expect TELS effects to become more consistent as teachers gain experience and we use embedded assessments along with teacher feedback to improve the modules. These findings also underscore the importance of professional development. Teachers in TELS have asked for additional opportunities to learn the pedagogy of knowledge integration.

Discussion

When students engage in inquiry and learn to integrate their ideas, they are prepared to apply what they learn in science classes to contexts beyond the classroom. For schools to teach inquiry and knowledge integration, both instruction and assessment need to change. Our findings and other similar studies show that typical multiple-choice science assessments are not sensitive to instruction designed to promote coherent (*17*, *18*) or deep understanding of science topics (*19*).

Assessments that require students to link and connect ideas clarify what we mean by inquiry learning and have the potential of stimulating lifelong scientific understanding. TELS students not only gained understanding of the topic they had studied but also learned to construct arguments, critique explanations written by their peers, and respond to feedback from their teachers. Just as students gain some advantage from experience with multiple-choice items (*20*), so might students benefit from experience constructing scientific explanations as encouraged in TELS modules.

TELS technologies enable students to connect scientific visualizations to their understanding of complex scientific ideas. They help guide students to make sense of visualizations rather than viewing them as amusing movies. These connections can benefit students in their future courses, prepare students to deal with scientific dilemmas, and encourage learners to view computer-presented information more critically.

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22. Based on work supported by NSF under grants 0334199 and 0455877. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the NSF. We thank O. L. Liu for help with the psychometric analysis, anonymous reviewers for helpful comments, and the TELS partners and the TELS schools for their dedication to improving science learning.

Supporting Online Material
www.sciencemag.org/cgi/content/full/313/5790/1049/DC1

10.1126/science.1131408