THE LEARNING SCIENCES AND GEOSCIENCE

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Too often, science instruction in the United States results in memorized details rather than linked or connected ideas. High stakes assessments can inadvertently reinforce this form of instruction with multiple choice items on isolated topics. In contrast students who conduct inquiry projects develop more cohesive, robust and coherent accounts of complex science and continue to develop their ideas after completing science classes. These students perform well on tests that require them to integrate their ideas into coherent arguments. To capture the excitement of science and stimulate knowledge integration by students, teachers, and district leaders, we advocate inquiry instruction which is well suited to learning in the geosciences.

Recent analyses of American textbooks conclude that students study “heavy books—light on learning” (AAAS, 1999) and that the United States curriculum is "a mile wide and an inch deep, with more topics covered than most other nations, but less time devoted to making sense of science" (Schmidt, Raisen, Britton, Bianchi, & Wolfe, 1997). As research on memory would predict (e.g., Bjork, 1994, 1999; Baddeley & Longman, 1978), this form of instruction leads to little cumulative learning and rapid forgetting. National assessments (O'Sullivan, Reese, & Mazzeo, 1997), international comparisons (Schmidt, McKnight, & Raizen, 1997), and state assessments (Blank, 2000) report dismal American performance in science. Most teachers and administrators learned science from courses that neglected the integration of knowledge and accumulation of understanding. Our proof-of-concepts investigations document that, as the result of conducting an inquiry project, students develop more cohesive, robust and coherent accounts of complex scientific topics and continue to develop their ideas after completing classes (Linn, Bell, & Davis, in press; Linn & Hsi, 2000; Linn & Slotta, 2000; Slotta & Linn, 2000).

The ***Web-based Inquiry Science Environment (WISE***) projects address aspects of geoscience [see interface below as well as http://wise.berkeley.edu]. WISE projects (see list below) have improved knowledge integration in studies of over 10 thousand students in varied educational contexts. These projects leverage modern technologies to flexibly adapt to new student populations as well as to local weather, geological features, or waterways. Flexibly adaptive projects also support customization by embedding assessment in the software to track student learning and teacher activities. Teachers, as part of professional development can modify the projects and their curriculum based on student progress.

WISE can promote knowledge integration in the geoscience curriculum by engaging students in inquiry: the intentional process of diagnosing problems, critiquing experiments, distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments. Inquiry projects promote knowledge integration by introducing new, normative ideas and by helping students link, evaluate, connect, critique, sort out, and test all of their ideas. Most science standards (NRC, 1996; AAAS, 1994; NRC, 1999; AAUW, 2000) mandate teaching science and technology as inquiry, yet 90% of teachers primarily use other methods (Becker, Ravitz, & Wong, 1999; Alberts, 2001; Horizon, 2001). Detractors argue that inquiry projects take time away from the numerous topics in the science standards. Advocates contend that technology-enhanced inquiry can help students become self-motivated learners of science and technology who continue to deepen their understanding even after completing the science curriculum.

WISE has established a mentored professional development program that has four features crucial for teacher knowledge integration. First, analysis of student ideas; second, reflection, which enables teachers to regularly review and enhance their ideas about a particular teaching strategy; third, pivotal cases that introduce new ideas for teachers to consider; and fourth, customization, that enables teachers to implement their ideas about effective teaching and redesign of WISE projects.

WISE responds to research on scaling by (1) creating a multidisciplinary partnership with a common vision for reform; (2) dynamically connecting curriculum, professional development, assessment, technology, and administrative policies; (3) developing technology-enhanced, flexibly adaptive curriculum materials and regularly refining them; (4) designing professional development that supports customization of materials by taking advantage of the local knowledge and creativity of teachers, administrators, and students; and (5) carrying out a research program with multiple indicators of success, opportunities to refine curriculum, instruction, and assessment based on performance as well as rigorous comparisons and longitudinal investigations.

The Scaffolded Knowledge Integration Framework.

WISE takes advantage of experimental research on science learning synthesized in the Scaffolded Knowledge Integration framework. Research on how individuals make sense of the natural world clarifies why inquiry instruction succeeds (Bransford, Brown, & Cocking, 1999; Piaget, 1971; Inhelder & Piaget, 1972; Scardamalia & Bereiter, 1996; Vygotsky, 1962). Learners develop scientific expertise by interpreting the facts, processes, and inquiry skills they encounter in light of their own ideas and experiences. Typically, students hold a repertoire of ideas about scientific phenomena and investigations (Driver, 1985; Driver, Leach, Millar, & Scott, 1996; Pfundt & Duit, 1991; Eylon & Linn, 1988; Slotta, Chi, & Joram, 1995). Inquiry instruction succeeds when learners engage in diverse ideas and engage in a process we call *knowledge integration*. This is a process where students make connections between their existing ideas, information from science class, observations, or alternative perspectives suggested by peers or experiments with the goal of developing more coherent, robust, and generative science knowledge (Piaget, 1971; Vygotsky, 1962; Scardamalia & Bereiter, 1991; diSessa, 2000; Linn & Hsi, 2000).

Knowledge integration responds to research documenting nonnormative ideas that students, teachers, and many adults develop from observing the world. Although often called misconceptions, these ideas reflect intellectual effort and keen observation. Early efforts to contradict misconceptions failed because students can easily hold conflicting views: One physics student explained that objects might remain in motion in class but they certainly come to rest on the playground. A knowledge integration approach requires students to find a mechanism to connect observations—like friction. WISE seeks to promote knowledge integration among all partners in education: students, teachers, policy makers at the school and district level, curriculum and technology designers, and professional development teams.

To promote knowledge integration, first WISE projects add powerful, normative ideas including pivotal cases to the views held by learners. Second, WISE guides learners to link, connect, sort out, reflect, critique, analyze, and organize knowledge such that it becomes more cohesive, generative, and useful. Knowledge integration around science occurs not only in science classes, but continuously in everyday situations as learners respond to news articles about science, personal dilemmas such as health decisions, and policy issues such as environmental stewardship. For example, the WISE project on genetically modified food spurs students to seriously consider complex topics like gene flow, critique persuasive messages, sort out alternative perspectives and make sense of conflicting information.

Knowledge integration has interpretive, cultural and deliberate aspects (Linn, 2001). Learners interpret new material in light of their own ideas and experiences, frequently relying on personal perspectives rather than instructed ideas. To take advantage of the interpretive nature of learning, WISE projects add *pivotal cases* that help students organize their ideas (Linn, in press). For example, students contrast genetic modification of the Hawaiian papaya in the 1900s with methods of crossing varieties of Irish potatoes in the 1800s. Learning happens in a *cultural context* where group norms, expectations, and social supports shape learner activity (Dewey, 1900, 1901; Vygotsky, 1962; Cole, 1996; Lave & Wenger, 1992) and impact views of who should be scientists in the future. WISE projects help students understand scientific advance by showcasing controversial aspects of science, engaging students in constructing arguments using evidence, and supporting debates where students negotiate norms and reach conclusions. WISE promotes equity by supporting diverse learners and ensuring participation of all students. Individuals make *deliberate* decisions about their own science learning, future course selection, and career choice. WISE projects direct energy towards knowledge integration by asking students to predict outcomes, test their ideas, and reflect on their progress to increase learning (e.g., White and Frederikson, 1998; Chi, 1996).

WISE Projects

WISE library projects (see the projects at http://wise.berkeley.edu)

Investigation Projects:
Awful Waste of Space... This project incorporates data collected by scientists to support students' exploration of planets found outside our solar system. Students think about, discuss, and model relationships between conditions that are necessary for life to begin on these newly discovered planets. Students also compare two methods that are currently in use to look for other life in the universe.
Creek Detectives. This project introduces Pine Creek, its location in the community, and its

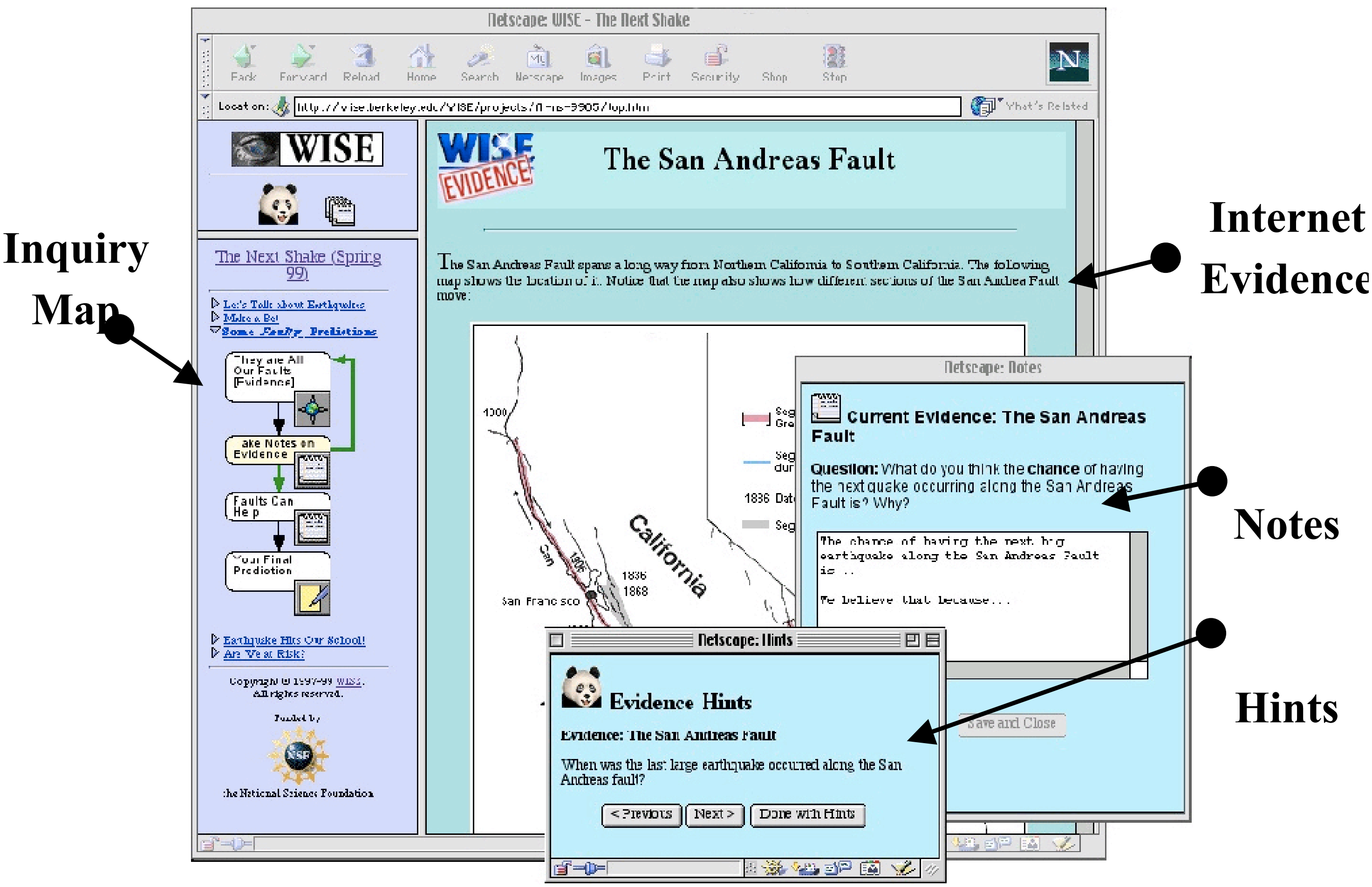
watershed. The project asks students to compare and contrast the creek at different points along the water path and at different seasons. Students learn about watersheds, what is carried in them, and how to make careful observations and predictions based on their observations at the local creek and online images.
Drink or Swim? Students learn about water quality by trying to answer the question about beach water; Would you drink or swim? Students read a story about two children who get ill from swimming in water, learn about water contaminants, and have a class discussion (both online and in the classroom) about water uses. The main goal is to teach students that depending on how water is used it can be safe or unsafe.
How do Earth and Space Plants Grow? In this project, students investigate different conditions for growing plants in space and growing plants on the earth. After thinking about the differences, they predict which plants are regular earth plants and which plants are NASA space plants. This will involve observing plant growth and development daily, collecting, and analyzing qualitative and quantitative data.
Pine Creek - Introduction. Students are invited to become detectives as they explore a local creek, its environment and ongoing status. Students participate in field trips, acquisition of data through water testing and observations, application of data to tables and charts, and interpretation of data for planning future trips and jobs at the creek. Students also upgrade the quality of the environment around the creek.
Probing Your Surroundings. Students explore thermal equilibrium in the context of the temperature of objects around them. After making predictions, and gathering data, students create and electronically discuss principles to explain that data. Students then go on to explore why objects feel hot or cold.
Rainforest Interactions. How might deforestation affect the endangered rainforest animal I have studied? This project explores trophic level interactions among species in a rainforest. It will be part of a multi-project rainforest study involving understanding some of the basic processes of ecosystems, analyzing some of the statistical data concerning deforestation, and developing viable conservation plans.
The Next Shake Project. In this project, students critically examine earthquake predictions made by others, and then come up with their own prediction for "the next big shake." They explore evidence from the World Wide Web that illustrates the effects of earthquakes on buildings and other structures. Using this evidence, they then evaluate how safe their own school would be during an earthquake.

What Makes Plants Grow? In this project, students will explore the factors needed to sustain plant life on earth such as soil, water, nutrients and light. They will utilize the World Wide Web to investigate the above factors required for optimal plant growth.
Yellow Starthistle: Briones Park. Yellow Starthistle is an invasive exotic plant pest throughout the western United States. In this project students first learn a little about the history and biology of the plant. Students study the results of a five year study. In the final activity students assume the role of one of the people impacted by the control plan in a presentation to a decision making board.
Controversy Projects:
California Flora - Native or Alien? In the "California Flora - Native or Alien?" project students learn about invasive non-native (alien) plants and three strategies for controlling or eliminating their impact. Students first learn to identify non-native plants in the area where they live and the major methods of intervention to control their spread. Students develop a plan which they present.
Controversy in Space. This project serves to introduce students to the role of controversy in advancing scientific discovery. Students investigate how scientists use evidence to support their claims.
Deformed Frogs - The Chemical Hypothesis. The Environmental Chemical Hypothesis investigates in more detail the argument that frog deformities are being caused by an environmental chemical that stimulates growth.
Deformed Frogs - The Parasite Hypothesis. This project gives more explicit information about the mechanism of the parasite hypothesis: observations and experiments by scientists; additional information about the complex life cycle of the trematode, some of which is spent in a tadpole; and Lefty the Frog, an important example that the parasite hypothesis has difficulty explaining.
Genetically Modified Foods in Perspective. The unit was designed with the goal of improving students' understanding of genetically modified foods: both their science content knowledge and their understanding of the complexity of this controversy. This requires students to think about the advantages and disadvantages of genetic engineering of foodstuffs and organic versus intensive farming.
How Far Does Light Go? Can light travel forever until absorbed, or does it eventually die out? Students are introduced to several pieces of 'evidence' which focus on different aspects of the physics of light. Students critique and organize this evidence in an attempt to answer the dilemma for themselves.
Malaria Introduction. In the "Malaria Controversy" project, students learn about three different

strategies for controlling the spread of malaria. Students analyze and examine evidence from the World Wide Web related to the malaria controversy. Students investigate the three suggested strategies for controlling the spread of malaria.
Origins. How did the universe come to be? This question serves as the entry point into students' exploration of sound and light waves, doppler effect, etc. Students use these concepts to explore the current debate between big bang and steady state theory. Students also explore creation stories from around the world in order to think about the role of religion and science in various cultures.
The DDT-Malaria Controversy. In this project, students critique the scientific evidence related to the productive uses and harmful side-effects of DDT. Based on what they learn about this pesticide and what they already know about malaria, they create an argument about the proposed global ban of DDT and present this argument during a classroom debate.
The Deformed Frogs Mystery. This project lays the foundation for the investigation of the nature and cause of frog deformities. This project can provide an introduction for in-depth investigation of the competing hypotheses involved in the controversy.
Wolves in your Backyard. This project first introduces students to the basic biology of wolves, addresses some frequently asked questions, as well as the nature of wolves. The project then presents some biology of predator-prey relations, and asks students to think about their own model for the food chain. Students explore the different perspectives of the wolf control controversy.
Critique Projects:
New Tabloid Trash or Serious Science Debate. Students study and apply a methodology for evaluating Internet materials to several different articles. Students then discuss and critique the way each group evaluated the articles.
Sunlight SunHEAT. Students learn about the topic of passive solar energy. Students also develop and apply criteria in the process of critiquing information found on the World Wide Web. Who wrote it and why? Are claims supported by evidence? What questions do you have after reading through the information?
Design Projects:
Ocean Stewards. This project teaches students about the ocean environment and the reasons for conducting expeditions within this environment. Students can explore six different National Marine Sanctuaries (NMS) in order to learn about the different marine habitats and the flora and fauna. Students will then prepare a proposal for an expedition within the chosen sanctuary.
What's in a House? In this project students design a house which would be energy efficient in a

desert environment. Their design is based on evidence which compares desert weather with their own local weather and how plants have adapted to the extremes of the desert climate.

The WISE environment



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