WISE Design for Knowledge Integration

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ABSTRACT: Scaling research-based curriculum to the multitude of science teaching standards and contexts has proven difficult in the past. To respond to the challenge, the Web-based Inquiry Science Environment (WISE) offers designers a technology-enhanced, research-based, flexibly adaptive learning environment. The learning environment can incorporate new features such as modeling tools or hand-held devices. Using WISE, design teams can create projects that bend but do not break when customized to support new school contexts and state standards. WISE curriculum projects are created by diverse design teams that include classroom teachers, technologists, discipline experts, pedagogy researchers, and curriculum designers. WISE inquiry projects incorporate Internet materials and build on the commitments and talents of teachers as well as the constraints and opportunities of their classroom contexts rather than imposing new practices without concern for past successes. These design teams create projects that incorporate diverse features of the WISE learning environment to form specific patterns that are then combined into whole projects. We refer to the whole projects as implementing *curriculum design patterns* for student activities. The projects are tested to determine how the curriculum design patterns promote knowledge integration, then reviewed by WISE researchers and revised accordingly (see M. C. Linn, P. Bell, & E. A. Davis, in press, Internet Environments for Science Education). Hillsdale, NJ: Erlbaum.). The most successful projects become part of the WISE library. This paper describes WISE design team practices, features of the WISE learning environment, and patterns of feature use in current library projects. The success of WISE in classrooms illustrates how flexibly adaptive projects can meet the needs of diverse teachers. Variation amongst library projects shows that designers can support inquiry with a wide variety of activities. Taken together, the library of projects and the success of students learning from them suggest that sustainable curricular innovations require extensive opportunities for customization and flexibly adaptive designs. *Sci Ed* **87:**517–538, 2003; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/sce.10086

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INTRODUCTION

Although most state and national standards call for inquiry instruction, few science classes include inquiry practices (Becker, 1999; Horizon, 2001). We define inquiry as engaging students in the intentional process of diagnosing problems, critiquing experiments, distinguishing alternatives, planning investigations, revising views, researching conjectures, searching for information, constructing models, debating with peers, communicating to diverse audiences, and forming coherent arguments. To create sustainable classroom inquiry instruction across the varied contexts where learning takes place, we created the Web-based Inquiry Science Environment (WISE). WISE integrates modern technologies to create flexibly adaptive materials that bend, not break when customized to support new school contexts and state standards. We align professional development, knowledge integration, and flexibly adaptive curricula to build on the commitments and talents of teachers as well as the constraints and opportunities of their classroom contexts rather than imposing new practices without concern for past successes (e.g. Corcoran, Shields, & Zucker, 1998; NSTA, 1996, 2001).

The WISE curriculum library includes 25 English language projects as well as projects in Norwegian, German, and Dutch, each created by a design team of researchers, teachers, technology specialists, and curriculum designers. The library projects have undergone classroom testing and demonstrated significant impact on student understanding. Approximately 1,000 teachers and 100,000 students have run WISE projects (see Table 1 for descriptions of the WISE library). By analyzing the use of WISE features, the implementation of knowledge integration patterns, the progress of students, and the performance of teachers, we illustrate how a learning environment can support local adaptation while sustaining a coherent science curriculum. Like other groups represented in this special issue, we find that incorporating inquiry with science courses requires materials that enable local adaptation along with support from multiple cycles of trial and refinement.

SUPPORTING KNOWLEDGE INTEGRATION

WISE research on learning, instruction, and partnership practices is driven by a knowledge integration perspective that guides the continuous improvement of the curriculum (Linn & Hsi, 2000). This knowledge integration perspective has developed in parallel with our technology-based learning environments to scaffold designers in creating inquiry curriculum projects and designing patterns of activities to promote knowledge integration for students and teachers. Our knowledge integration perspective has been refined through substantive debate, extensive classroom research, and input from a broad range of related research programs (Bransford, Brown, & Cocking, 1999; Brown & Campione, 1994; Champagne, Klopfer, & Anderson, 1980; diSessa, 2000; Driver, 1985; Glaser, 1976; Richard, 1993; Scardamalia & Bereiter, 1992; Vanderbilt, 1997; White & Frederikson, 1998).

The knowledge integration perspective is founded on two central findings. First, learners hold multiple conflicting ideas about virtually any scientific phenomenon (diSessa, 2000; Eylon & Linn, 1988; Linn & Hsi, 2000; Slotta, Chi, & Joram, 1995). Some conflicting views connect to context (e.g., objects in motion come to rest on the playground but remain in motion in science class). Some come from everyday practices (e.g., heat and temperature both come out of the furnace; you can turn up either the heat or temperature, but heat is the temperature range on a thermometer). Others result from efforts to integrate confusing evidence (e.g., the metal feels colder than the wood in this room, but the thermometer says they are the same temperature). Thus, students bring to science class multiple conflicting views of scientific phenomena, often tied to specific contexts, examples, experiences, or

TABLE 1
WISE Library Projects[a]

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 multiproject 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 explore the factors needed to sustain plant life on earth such as soil, water, nutrients and light. They 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 5-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.

Continued

TABLE 1
WISE Library Projects[a] (*Continued*)

Controversy Projects

California flora—Native or alien? In the "California Flora—Native or Alien?" project students learn about invasive nonnative (alien) plants and three strategies for controlling or eliminating their impact. Students first learn to identify nonnative 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.

Continued

TABLE 1
WISE Library Projects[a] (*Continued*)

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.

[a]See the projects at http://wise.berkeley.edu.

situations. Second, learners deliberately develop their repertoire of views concerning a given scientific phenomenon. Often, in collaboration with others, learners invest intellectual energy in sorting out, linking, connecting, critiquing, reconsidering, prioritizing, selecting, and organizing their ideas (Asabel, 1978; Linn, 1980; Novak & Gowin, 1984). The intellectual energy that students bring to science, if harnessed, could dramatically improve scientific understanding and make scientific thinking a more lifelong process.

WISE design teams use the knowledge integration perspective to create inquiry projects that help students develop a more cohesive, coherent, and thoughtful account of scientific phenomena. The knowledge integration perspective suggests a general instructional *pattern* that involves eliciting the repertoire of student ideas, adding promising normative ideas to the mix, and supporting the process of combining, sorting, organizing, creating, and reflecting to improve understanding. WISE design teams create more precise, specialized, discipline-focused, and unique patterns of activities and technology features to tailor this general pattern to their specific goals, technology tools, and instructional contexts.

THE WISE LEARNING ENVIRONMENT

Building on earlier learning environment technologies, the WISE partnership created the first iteration of our current platform-independent web-based learning environment in 1996 (Bell, Davis, & Hsi, 1995; Linn & Slotta, 2000). We created an authoring environment to enable design teams to rapidly create and refine curriculum projects by taking advantage of all the features developed by earlier design teams as well as promising work on technology-enhanced learning environments by other investigators (diSessa, 1992; Edelson, Gordin, & Pea, 1999; Feurzeig & Roberts, 1999; Kafai & Resnick, 1996; Songer, Lee, & Kam, in press; Vanderbilt, 1997; White & Frederickson, 1998).

WISE (see Figure 1) incorporates an inquiry map to communicate the patterns that students follow to investigate a topic. The map enables students to work individually and

Figure 1. The WISE environment, showing the inquiry map for the Deformed Frogs project (left hand frame of main browser window), as well as pop-up windows for reflection notes and hints.

independently on their projects, rather than constantly asking the teacher for guidance on what to do next (Feldmann, Konold, & Coulter, 2000; Edelson, Gordin, & Pea, 1999; Linn & Hsi, 2000). WISE incorporates prompts to help students reflect as well as monitor their progress. WISE also includes hints and evidence pages designed to add ideas about the topic the student is researching. The inquiry map presents curriculum designers with a tradeoff. If inquiry steps are too precise, resembling a recipe, then students will fail to engage in inquiry. If steps are too broad, then students will flounder and become distracted. Finding the right level of detail requires trial and refinement and, in some cases, customization to local conditions and knowledge. Therefore, the inquiry map itself may need customization depending on students' prior experience with inquiry and their level of understanding of the inquiry question.

WISE has investigated a process of collaborating with others both locally and around the world to create new inquiry projects. Many scientific societies, governmental agencies, museums, outreach programs, and educational institutions regularly develop science curriculum. By collaborating with WISE, these groups can take advantage of recent educational research and create flexibly adaptive projects using WISE software features and patterns. In turn, WISE has responded to these groups by creating new features to meet their disciplinary needs. The 25 English language projects currently in the WISE library, together with the

Project Name	Project Type	Standard WISE Features					Optional Features: Accessible		Visible									Social				Autonomous			
		Evidence/Information Pages	Inquiry Map	Assessments	Hints on Demand	Notes/Journal	Pop-Up Alert	Hints as Activity Steps	Causal Mapper	Data Grid	Sensemaker	WiseDraw	Show All Work	Online Graphing	DataGathering	Visualizations/Simulations	Data Visualizer	Online Discussion	Electronic Show-n-Tell	Branching/Hinging Steps	In-Class Debate/Presentation	Write Report	Design Solution	Create Principle	Offline Worksheets/Journal
Awful Waste of Space	Investigation	Y	Y	Y	Y	Y	Y		Y	Y								Y	Y		Y		Y		
Creek Detectives	Investigation	Y	Y	Y	Y	Y			Y												Y				
Drink or Swim?	Investigation	Y	Y	Y	Y	Y											Y	Y							
How do Earth and Space Plants Grow?	Investigation	Y	Y	Y	Y	Y	Y	Y				Y		Y	Y				Y				Y		Y
Pine Creek - Introduction	Investigation	Y	Y	Y	Y	Y			Y					Y	Y		Y				Y	Y			
Probing Your Surroundings	Investigation	Y	Y	Y	Y	Y									Y	Y		Y						Y	
Rainforest Interactions	Investigation	Y	Y	Y	Y	Y			Y							Y		Y	Y	Y	Y				Y
The Next Shake Project	Investigation	Y	Y	Y	Y	Y										Y									
What Makes Plants Grow?	Investigation	Y	Y	Y	Y	Y	Y	Y										Y							
Yellow Starthistle:Briones Park	Investigation	Y	Y	Y	Y	Y				Y					Y										
California Flora - Native or Alien?	Controversy	Y	Y	Y	Y	Y												Y					Y		
Controversy in Space	Controversy	Y	Y	Y	Y	Y																			
Deformed Frogs - The Chemical Hypothesis	Controversy	Y	Y	Y	Y	Y	Y	Y														Y			
Deformed Frogs - The Parasite Hypothesis	Controversy	Y	Y	Y	Y	Y	Y	Y														Y			
Genetically Modified Foods in Perspective	Controversy	Y	Y	Y	Y	Y										Y		Y		Y	Y	Y			Y
How Far Does Light Go?	Controversy	Y	Y	Y	Y	Y	Y	Y			Y		Y							Y	Y				Y
Malaria Introduction	Controversy	Y	Y	Y	Y	Y												Y					Y		
Origins	Controversy	Y	Y	Y	Y	Y						Y			Y	Y		Y			Y				Y
The DDT-Malaria Controversy	Controversy	Y	Y	Y	Y	Y		Y			Y	Y						Y							
The Deformed Frogs Mystery	Controversy	Y	Y	Y	Y	Y																			
Wolves in your Backyard	Controversy	Y	Y	Y	Y	Y			Y									Y			Y		Y		
Protect from AIDS	Critique	Y	Y	Y	Y	Y	Y											Y			Y				
Sunlight SunHEAT	Critique	Y	Y	Y	Y	Y	Y						Y		Y						Y			Y	
New Tabloid Trash or Serious Science Debate	Critique	Y	Y	Y	Y	Y					Y							Y							
Ocean Stewards	Design	Y	Y	Y	Y	Y					Y							Y		Y	Y		Y	Y	
What's in a House?	Design	Y	Y	Y	Y	Y												Y		Y			Y		
Frequency of Feature Use		26	26	26	26	26	8	6	5	2	4	3	2	2	6	5	2	15	3	5	11	4	7	3	5

Figure 2. WISE features in library projects (view screenshots of optional features by clicking on "The WISE Environment" at http://wise.berkeley.edu/pages/about.php).

projects authored by Norwegian, Dutch, and German design teams, represent collaborations with these diverse groups including the 1000 Friends of Frogs, the International Wolf Center, the University of California—Berkeley Pledge, the American Association for the Advancement of Science, NOAA, NASA, The Monterey Bay Aquarium, and the Berkeley Botanical Gardens. Each of these projects, summarized in Table 1, focuses on a compelling inquiry question such as, "Should local farmers plant genetically modified crops?" All of the projects take advantage of the standard WISE learning environment features, and most also use one or more optional WISE features (see Figure 2 as well as "Learn About WISE" at http://wise.berkeley.edu for more information about these features). Many of the optional WISE features were designed for specific library projects and adopted by other projects once they became available.

CURRICULUM DEVELOPED BY DESIGN TEAMS

Each project is developed by a WISE design team including pedagogical specialists, scientists (i.e., from our various partner agencies and groups), science teachers, and technology designers. WISE offers design teams a flexibly adaptive learning environment that incorporates proven technology features and supports promising instructional patterns. These design teams have produced WISE curriculum for many different topics and student age groups. For example, NASA partnerships designed the *Rats in Space* project, where high school biology students critique the use of rats as models for humans in NASA bone loss studies, as well as the *Sprouting Space Plants*, where fourth and fifth graders design a terrarium to compare the growth of NASA *fast plants* with regular earth plants. Lawrence Berkeley Laboratory scientists contributed to a project where students design a house for a desert climate by critiquing energy efficient house designs on the Web, completing design worksheets, and discussing their design ideas online.

Design Practices

The WISE authoring software supports knowledge integration through its technology features and curriculum design patterns. These patterns are based on our scaffolded knowledge integration framework as discussed in the next section. Designers can thus create inquiry projects that incorporate tested patterns, or even take advantage of an existing WISE project and modify it for their topic area. Once a project draft is completed, the design team decides how to test the project and creates an assessment plan. Usually the test occurs in a class taught by a teacher who is a member of the team. Design team participants observe the teaching and, based on their observations as well as the progress of students using the project, iteratively refine the project (e.g. Davis & Linn, 2000; Linn, Shear, Bell, & Slotta, 1999; M. C. Linn & M. Williams, in preparation).

After more testing and refinement, the project becomes eligible for the WISE library where it will include a suite of assessments including pretests, posttests, embedded activities, and scoring rubrics. Library projects also have lesson plans and commentary from teachers who have used the projects. In reviewing WISE projects under development, our partnership draws on examples of student work, assessments, results, and classroom observations, if possible. Library projects undergo further revision based on their use by new teachers. Typically, in conjunction with professional development, teachers customize WISE library projects after teaching and becoming familiar with the project (Linn & Slotta, 2000). WISE facilitates flexible revision and improvement based on classroom trials in this way. Teachers can also easily customize the projects to match their curriculum and students. This flexibility empowers users to test alternative ideas, analyze weaknesses in instruction, and redesign instructional materials to meet student needs, and the affordances of specific teaching contexts. The WISE partnership continuously synthesizes these experiences to build a more coherent body of design knowledge.

GUIDING PROJECT DEVELOPMENT: THE SCAFFOLDED KNOWLEDGE INTEGRATION FRAMEWORK

To support design teams in creating projects, we have refined the Scaffolded Knowledge Integration framework and developed design principles (Linn & Hsi, 2000). The framework has four main tenets including (1) making thinking visible, (2) making science accessible, (3) helping students learn from each other, and (4) promoting lifelong learning. WISE has developed patterns of features to effectively implement the framework in inquiry projects. These four tenets lead to curriculum design patterns composed of features and activities within WISE projects to effectively promote knowledge integration. Curriculum design patterns are captured in whole projects that are often cloned to create new projects or customized to meet the needs of specific teachers, contexts, settings, and instructional goals.

Making Science Accessible in WISE

When science ideas are accessible, students can restructure, rethink, compare, critique, and analyze both the new ideas and their established views. Making science accessible means designing science content. Too often, curriculum materials are decreed by standard-setting groups or textbook authors without research to demonstrate whether they benefit students. Textbook authors may create disconnected, confusing accounts of science topics because their materials receive such limited testing. Clement (1998) argues that texts often use examples, such as cars driving on icy roads to illustrate frictionless surfaces, that students find inaccessible. Students studying high school physics often lack driving licenses and experience on icy roads. Other research programs (Linn, Eylon, & Davis, in press) illustrate how default decisions, such as depicting chemicals as being composed of single molecules, promote nonnormative student ideas, such as assuming that each molecule has color, viscosity, or a boiling point. Even when materials are tested with students, designers often simplify vocabulary rather than altering instruction to promote knowledge integration. Vocabulary simplification may actually reduce the impact of written material (e.g., Ausubel, 1978; Kintsch, 1998) rather than promote knowledge integration.

Designing science content involves selecting the scope, grain size, examples, and detail for scientific material such that it connects to prior instruction and current student ideas. In WISE this starts with carefully selecting the inquiry question. Inquiry questions for WISE library projects are summarized in Table 1. The scope of the inquiry question determines the level of knowledge integration students are likely to achieve. A broad scope, such as, "How can we control the worldwide threat of malaria?" may succeed for expert science policymakers but motivate science students to platitudinous conclusions. In contrast, the WISE Cycles of Malaria project asks students to allocate funds among three alternatives for dealing with the worldwide malaria threat: developing a vaccine, spraying with DDT, and mandating individual practices such as eliminating standing water or using treated bednets. Students studying these compelling alternatives discuss complex tradeoffs such as whether to use DDT which harms birds but saves infants. They analyze why vaccine research takes so long to achieve a cure and discuss the likelihood of changing individual practices among people who are poor, hungry, and isolated in many malaria-infested regions (Slotta, in press).

Selecting the grain size and level of analysis for a WISE project is important to the process of knowledge integration. For example, the design team authoring the WISE Deformed Frogs project investigated evidence describing the similarities in the molecular structure of pesticides and growth hormones. Students in middle school who had not studied molecular structures were confused. However, these same students could draw conclusions from evidence connecting levels of parasites and pesticides in ponds with frequency of frog deformities (Linn et al., 1999). To help students engage in inquiry, the design team created accessible evidence as well as inquiry supports to reduce the complexity of the debate. Classroom observations suggested that a traditional molecular biology approach was too complicated and that an approach focusing on the two main hypotheses and the evidence in terms of pesticides and parasites provided a more promising starting point.

Many WISE design teams have made WISE inquiry projects accessible by providing rather detailed steps for the first inquiry investigation and then providing less detailed steps to fade scaffolding in subsequent projects. For example, in Deformed Frogs, the introductory project is quite specific but the Chemical Hypothesis and the Pesticide or Parasite Hypothesis projects encourage students to look on the Internet for additional evidence and interpret original science sources.

Many decisions contribute to making WISE inquiry accessible. Often, our scientist partners want evidence pages to provide a complete scientific account of the problems, worrying that students will fail to gain normative understanding of the topic because of lack of detail. In contrast, teachers and classroom observers frequently point out that students skip long, detailed evidence pages because they cannot ascertain the connections to their project. They advocate an initial page that provides an entry into the disciplinary knowledge and hyperlinks for students who wish more detail. Surprisingly, making science accessible may not mean making it simple (Kintsch, 1998). Rather, students need a nudge so they can get started on the difficult process of knowledge integration. Teachers often use WISE hyperlinks to add hints and glossary annotations to WISE evidence pages to overcome obstacles that appear to derail knowledge integration.

Designing contexts for problems that connect to students' personal concerns can motivate students to reconsider and revisit their ideas long after science class is over. As the WISE library projects illustrate, identifying compelling contexts for inquiry requires substantial creativity. For example, the earthquake design team initially focused the Next Shake activity on predicting when the next big earthquake might occur. Even in California, this turned out to be less personally relevant to students than analyzing the likelihood of an earthquake occurring at their school or home. Focusing the activity on the school site, analyzing the nature of the land where the school was built, and learning about the construction materials used to build the school, enabled students to gain a deeper understanding of the impact of earthquakes and prepared them to analyze the danger from earthquakes in new situations. The teacher found, however, that students had difficulty determining the building materials in their homes. While they could all interpret information concerning the construction of their school, they were not able to easily determine how their homes were constructed. In the revision, the designers strengthened the geological analysis, directing students to on-line information about local faults, and reduced reliance on home construction information.

Designers also make crucial science concepts accessible with pivotal cases (Linn, in press; Linn & Hsi, 2000). Pivotal cases use a natural experiment to illustrate an important comparison that brings the science concept to life and enables students to use their inquiry skills to reorganize their ideas. For example, in a project debating whether light goes on forever or dies out, students often have trouble distinguishing visual acquity from light propagation. The pivotal case comparing sunglasses and night vision goggles that amplify light not visible to the naked eye helps students sort out their views (Bell & Linn, 2000). Another successful pivotal case involves comparing the feel and temperature of objects in a hot car and a cold room. Students use these comparisons to clarify why objects feel different even if they are the same temperature (Clark, in press). These pivotal cases impact lifelong science learning by scaffolding students in reconstructing their understanding of science topics (Linn, in press).

All of the WISE features discussed in this section, including evidence pages, the inquiry map, pivotal cases, and the inquiry question itself, contribute to making science accessible. These features work best when combined in patterns. For example, a common WISE pattern asks students to make a conjecture, review an evidence page, and reflect on their ideas. A pattern with pivotal cases involves eliciting ideas in a discussion, introducing the pivotal case, and asking students to construct explanations.

Review criteria to determine whether a WISE project has made science accessible include analyzing the scope of the project, the grain size of examples, the level of analysis of the science, and the relationships to the broader curriculum. We analyze the inquiry patterns in the WISE inquiry map to determine whether students view them like a recipe, or like an opportunity for inquiry. In addition, we review projects and students work to determine whether the level of analysis makes sense for the students completing the project. We also determine, based on classroom observation and analysis of student notes, whether students have sufficient opportunity for inquiry.

Making Thinking Visible in WISE

When researchers call for making thinking visible (e.g., Collins, Brown, & Hollum, 1991; Vanderbilt, 1997) they refer to at least three possibilities. For some, making thinking visible means making student thinking visible for purposes of assessment. When teachers have access to student ideas, they have the opportunity to make courses more effective and can use this information to assign grades and determine student progress. Some advocate making the thinking of teachers visible to help students understand how scientific problems are solved. For example, Linn and Clancy (1992) reported that computer science instructors frequently only provide an accurate account of a problem solution, rather than describing wrong paths or debugging practices. To help make design practices visible, they devised case studies detailing a broader set of inquiry activities as well as promising patterns (Linn & Clancy, 1992). Others seek to make scientific thinking visible by creating models, simulations, and visualizations (Edelson, Gordin, & Pea, 1999; Linn & Hsi, 2000). Some fields of science, including molecular biology and meteorology have benefited substantially from new visualization tools that might be customized for students. A variety of WISE features help project designers make thinking visible in all three of these ways as described below.

To make students thinking visible for purposes of assessment, WISE prompts invite students to report on their ideas. One primary vehicle for these prompts and reflection is the Notes window (see Figure 1). Davis and Linn (2000) report that prompts have varied impacts on students. Some prompts, rather than revealing student ideas, motivate groups of students to respond that they already know the material. Prompts can serve as useful embedded assessments, helping teachers improve their instruction and guiding designers in making revisions (e.g. Linn & Hsi, 2000; Slotta, in press). By analyzing student notes using a common metric, teachers can also compare progress from the beginning to the end of a project and look for points where students encounter difficulties.

Design teams have used WISE prompts for a broad range of student activities. To determine the range of prompts in WISE we reviewed over 450 prompts in the 25 library projects and coded them in 5 categories, as shown in Table 2. We found three forms of epistemological or metacognitive prompts and four forms of knowledge integration prompts. Epistemological prompts ask students to reflect on the nature of science. Students might explain why scientists disagree about the causes of frog deformities, for example. Metacognitive prompts ask students to critique their own progress or analyze their own knowledge. Because of small size we collapsed these into one category. Knowledge integration prompts ask students to link and connect ideas. We distinguish among four types of knowledge integration prompts that vary in the scope of integration refinement: overarching, critique, interpretation, and explanation.

The distribution of prompts for the 25 library projects appears in Figure 3. As this figure shows, design teams take advantage of prompts for knowledge integration, using all four of the categories but generally neglect epistemological and metacognitive prompts. Especially for controversy projects, adding epistemological prompts could enhance student understanding of the nature of science (Bell & Linn, 2002). The WISE review process has incorporated these findings to help designers create more comprehensive prompts.

WISE prompts allow designers and teacher customizers to elicit from students many aspects of their thinking. Design teams can use student notes for activity revision. Examination of notes when students conduct experiments, go on field trips, or search for novel web pages show designers and teachers whether students are engaging in knowledge integration.

TABLE 2
Coding Scheme for Prompts

Epistemology and Metacognitive Prompts—Focus on Knowledge

Epistemological. Epistemological prompts focusing on nature of science, how science is conducted, and nature of representations. When a prompt might be coded either Epistemology or Critique/Compare, Epistemology outweighs Critique/Compare. In particular, prompts focusing on the reliability or credibility of a piece of evidence receive this code.

Monitoring. This metacognitive prompt asks students to assess, monitor, or evaluate their progress in the activity.

Predicting. This metacognitive prompt asks students to make predictions and to reflect on their knowledge at the beginning of a project or activity. For example, "make and justify a selection" and "what will happen?" kinds of questions ask for predictions when the students have only their prior knowledge to draw upon.

Knowledge Integration Prompts—Focus on the Discipline

Overarching. These prompts ask students to connect their views about the whole project topic. Examples include: "How do we use all of this information to solve the problem?," or, in a debate, "Which side would you choose and why?" or for any driving question project, responding to the driving question such as "How would you respond to the malaria problem?."

Critiquing. These prompts ask students to critique, apply criteria, or make comparisons. For example, "Strengths and weaknesses," "pros and cons," "same or different," "describe and compare," or "is this good or bad?" These prompts assess the science content, not the reliability or credibility of the source.

Interpreting. These prompts ask students to reinterpret a piece of evidence in terms of the project question, a new case, or a new view. They are narrower than the overarching prompts.

Explaining. These prompts ask students to explain one piece of evidence in their own words. They generally direct students to report or explain the evidence without as much interpretation. These prompts could as ask students to collect data by recording temperatures, measuring pH, etc.

To make teachers' thinking visible in response to students' notes or other activities, WISE supports feedback and grading of student work. Teachers can read student notes and compose both general and specific comments. Teachers often compose general comments and then customize them slightly for each student. In response to design team requests, WISE has enhanced the teacher grading and feedback features (by joining WISE at http://wise.berkeley.edu the reader can see all teacher tools at. http://wise.berkeley.edu/teacher/management.php).

WISE design teams have created models, simulations, and other representations of scientific phenomena to make scientific ideas visible to students. Typically, materials that make thinking visible appear as evidence pages in WISE. For example, in the Genetically Modified Foods project, students can interact with a model of gene flow to understand how genetically modified crops might infiltrate crops in adjacent areas. This model is introduced as part of a pattern that includes making predictions, running the model, representing data, running it again, and making conclusions. For the thermal equilibrium pivotal case investigated in the Probing Your Surroundings project, visualizations provide an effective tool to help students make connections between thermal equilibrium, conductivity, and why objects feel the way they do (Clark, in press). In addition to visualizations, WISE design teams have frequently requested tools to support student thinking that make student ideas visible. For example,

Project Name	Type	Runs Year	Prompts					Total Prompts
			Epist/Meta	Overarching	Critique	Reinterpret	Explain	
Awful Waste of Space	Investigation	75	26%	17%	9%	22%	26%	23
Creek Detectives	Investigation	1250	0%	8%	33%	17%	42%	12
Drink or Swim?	Investigation	1500	27%	27%	0%	9%	36%	11
How do Earth and Space Plants Grow?	Investigation	326	60%	0%	10%	30%	0%	10
Pine Creek - Introduction	Investigation	97	14%	38%	0%	29%	19%	21
Probing Your Surroundings	Investigation	285	54%	17%	0%	21%	8%	24
Rainforest Interactions	Investigation	795	11%	22%	11%	33%	22%	9
The Next Shake Project	Investigation	2000	31%	16%	0%	34%	19%	32
What Makes Plants Grow?	Investigation	1189	17%	25%	0%	8%	50%	12
Yellow Starthistle:Briones Park	Investigation	4	0%	50%	0%	50%	0%	2
Investigation Project Total		*7521*	24%	22%	6%	25%	22%	16
California Flora - Native or Alien?	Controversy	17	29%	14%	0%	36%	21%	14
Controversy in Space	Controversy	3000	50%	0%	0%	25%	25%	4
Deformed Frogs - The Chemical Hypothesis	Controversy	760	0%	17%	0%	83%	0%	6
Deformed Frogs - The Parasite Hypothesis	Controversy	1110	0%	0%	0%	100%	0%	7
Genetically Modified Foods in Perspective	Controversy	900	11%	7%	14%	18%	50%	28
How Far Does Light Go?	Controversy	850	12%	12%	0%	76%	0%	17
Malaria Introduction	Controversy	2500	19%	13%	44%	6%	19%	16
Origins	Controversy	148	19%	7%	19%	52%	4%	27
The DDT-Malaria Controversy	Controversy	387	0%	0%	20%	70%	10%	10
The Deformed Frogs Mystery	Controversy	28	25%	0%	0%	75%	0%	8
Wolves in your Backyard	Controversy	3000	7%	40%	20%	13%	20%	15
Controversy Project Total		*12700*	15%	10%	11%	50%	14%	14
Protect from AIDS	Critique	700	50%	8%	0%	42%	0%	12
Sunlight SunHEAT	Critique	288	39%	0%	18%	18%	24%	38
New Tabloid Trash or Serious Science Debate	Critique	713	100%	0%	0%	0%	0%	25
Critique Project Total		*1701*	63%	3%	6%	20%	8%	25
Ocean Stewards	Design	440	13%	21%	21%	0%	46%	24
What's in a House?	Design	273	13%	19%	28%	28%	13%	32
Design Project Total		*713*	13%	20%	24%	14%	29%	28

Figure 3. Frequency of prompt use and prompt characteristics of library projects.

design teams wished for graphing and exploratory data analysis tools that are now part of WISEdraw. These tools enable students to record such information as the rate of plant growth and the rate that a plant goes through its life cycle, both on the same representation.

Motivated by research suggesting that representations enhance students' understanding of scientific material, members of WISE design teams have created argument representation tools such as SenseMaker (Bell, 1998; Bell & Linn, 2002). SenseMaker allows students to represent arguments about complex scientific topics such as, *How far does light go*? or, *The DDT Debate: Controlling Malaria at a Cost*. Students use WISE Evidence Pages in these projects to shape their arguments. These evidence pages include both existing Web resources as well as Web pages authored by the design teams. SenseMaker representations of arguments play a number of roles in student activities, including the facilitation of the group construction of an argument for a debate. SenseMaker arguments not only make the relationships among scientific material visible to students, they also allow teachers to see how student ideas are constructed and allow other groups of students to inspect the arguments of their peers.

Modeling and simulation tools can also make both scientific ideas and students' thinking about those ideas visible (White & Frederikson, 1998). The WISE Causal Modeler provides a descriptive account of the relationship among factors influencing a complex system. For example, the Causal Modeler (Baumgartner, in press) enables students to represent the relationships among factors influencing water quality. The tool fits in a pattern where students build an initial model, test creek water, revise their model, compare results to findings from prior years, and record differences. The modeling enables students to compare their view of the relationship to those of their peers as well as to the views held by expert scientists. Other research groups (Krajcik et al., 2000; Wisnudel-Spitulnik, Krajcik, & Soloway, 2000) provide additional functionality in that students can also run their models and test their hypotheses against data from various streams and rivers as part of the project. These groups use a similar curriculum design pattern.

A variety of WISE features enable teachers, students, and expert scientists to make their thinking about scientific phenomena visible. Visualizations can confuse, rather than inform (Hegarty et al., 1999), so WISE designers often refine these tools many times. Prompts can direct attention to productive knowledge integration or distract students from their task. Argument maps, models, simulations, and graphing environments all offer desirable representations for inquiry, but each of these tools takes time to learn. Generally, design teams seek balance by focusing on a few of these features for making thinking visible in a project rather than combining a large number of them (see Figure 2).

Making thinking visible is a component of knowledge integration that succeeds better when combined in a curriculum design pattern with other activities that encourage synthesis of information. Patterns that include making thinking visible generally ask students to test their ideas against recognizable criteria and hold their ideas up to established standards.

Review criteria to determine whether WISE projects make student, teacher, and scientific ideas visible include ensuring that the ideas made visible connect to other information and perspectives. In addition, efforts to make thinking visible should elicit the full range of ideas that students maintain in their repertoires. Generic prompts, for example, connect to more ideas than specific prompts. Inevitably, requiring students to make their thinking visible or to analyze the thinking of others must balance with opportunities for students to reflect and monitor their own progress. As the analysis of prompts shows, designers so far have tended to neglect some promising areas. To assess the balance in a set of prompts, reviewers use the categories in Table 2. Ideally, designers will include a balance among analyzing ideas, sifting and sorting perspectives, reflecting on the nature of science, and self-monitoring.

Learning From Each Other in WISE

When students learn from each other they encounter a broad range of views that help them sort out promising ideas and enable them to establish criteria for distinguishing ideas. Vygotsky argued that peers and teachers can create what he called a zone of proximal development that supports knowledge integration. Many researchers demonstrate benefits for students learning from others (Aronson, 1978; Brown & Campione, 1994; Hoadley & Linn, 2000; Scardamalia & Bereiter, 1996). Linn and Hsi (2000) report that when students work in groups of two, they engage in productive discourse more often than when they work in larger groups. Scardamalia and Bereiter (1996) illustrate how groups can form norms for scientific discourse when their online discussions include comments from the classroom teacher. Structuring collaboration in conjunction with other features of the learning environment such as making thinking visible is a powerful way to construct a curriculum design pattern.

Indeed, structuring collaboration requires balancing the powerful and nonnormative ideas that peers can introduce into the mix of notions students consider. Furthermore, in peer learning situations, individuals can discourage others from knowledge integration by suggesting that they, as individuals, or as members of a cultural group, do not belong in science. To remedy these problems, WISE incorporates peer learning into curriculum design patterns that also encourage groups to form norms and criteria for knowledge integration and select among ideas using these norms as part of online or face-to-face collaborations. This forming of norms and criteria and selection of ideas using the norms is an epistemic process also reflected in prompts coded as epistemological. WISE project designers can use patterns to connect important epistemic and content concepts to criteria. WISE patterns also emphasize norms of discourse, by helping peers respect each other and to respond to ideas, not stereotypes about who belongs in science or mathematics. Designing instruction so that students can make anonymous contributions to discussions has also proven beneficial for reducing or eliminating responses based on stereotypes (Hsi, 1997). Overall, encouraging students to engage in discussions designed to highlight alternative ideas offers an additional promising approach to supporting knowledge integration.

The WISE inquiry map helps students learn from each other by supporting pairs as they work on WISE projects. When students work together, they have the opportunity to critique and revise each others' ideas and can respond to guidance. Teachers play an important role in helping students balance their contributions to WISE projects and mentoring programs. Teachers may require student groups to switch the keyboarding person halfway through class periods, or ask students to explain each contributor's role in the final project.

WISE discussion tools support incorporating peer learning into curriculum design patterns. Online asynchronous discussions enable students to make their ideas visible and inspectable by their teachers and peers and give students sufficient time to reflect before making contributions. Hsi (1997) reports that under these circumstances, students warrant their assertions with two or more pieces of evidence and over ninety percent of the students participate. In contrast, Hsi observed that only about 15% of the students participate in a typical class discussion, and that few statements are warranted by evidence. Picking topics with appropriate scope, related resources, and connections to student interest also makes discussions more accessible to students. Designers often have difficulty framing discussion topics clearly and frequently an iterative refinement process improves discussion activities. Hsi (1997) found that asking students for their opinions prior to allowing them to contribute to the discussion improved the overall interaction because students included a more diverse set of ideas.

Another WISE feature called Show and Tell supports peer review of projects. Students can make any portion of their project work visible to their peers and solicit comments. Developed in response to requests from several design teams, this new WISE feature fits into a pattern where students gather and explain data, solicit one or two peer reviews of their work, and incorporate student comments into their report.

The WISE branching feature also encourages students to learn from each other. In the branching pattern, designers can direct students to specialize in one of several topics (Aronson, 1978). Specialists then communicate their ideas to their peers and respond to questions about their perspective. As a result, students learn to develop explanations that make sense to their peers. In a variation on the Japanese IKATURA method (Clark, in press; Cuthbert, Clark, & Linn, 2002), students conduct experiments, construct principles, and enter their principles as a starting point for the discussion. During the discussion, students comment on the principles proposed by other students. Students then respond to the comments others have made about their own principles. In this approach, discussions support comparison, clarification, and justification to formulate more cohesive and coherent principles (Clark, in press).

In WISE debates, students research a topic, develop an argument, and resolve a scientific question with their peers. WISE debates follow several formats. In one pattern students prepare a presentation about either side of the argument and the teacher calls randomly on students to present their arguments. During each presentation, each member of the class is required to write down a question for the presenters. Some students ask their questions and all students submit their questions to the teacher for grading purposes. Students learn from the debate and also from framing questions. This debate format rewards those who understand the issues and can write critical questions rather than students who interrupt discussion or shout out ideas. Another debate pattern involves preparing an argument, participating, and working a report to integrate ideas (Bell, in press).

As these examples illustrate, peer learning activities work best to promote knowledge integration when they are part of a curriculum design pattern that includes other inquiry features. These patterns emphasize researching, explaining, reflecting, communicating, and defending ideas as well as revising ideas based on feedback. WISE software also promotes knowledge integration by making in-class, peer-to-peer discussions inspectable by teachers and researchers. Using this resource, reviewers of WISE projects can determine whether WISE projects help students learn from each other. They can assess opportunities for students to interact as well as supports for students to set common norms for scientific discussion. Reviewers can also address how the project deals with stereotyped beliefs about who succeeds in science and whether discussions elicit comments from every student.

Promote Autonomous Lifelong Learning in WISE

WISE projects prepare students to become lifelong learners by engaging them in carrying out complex projects and regularly critiquing, comparing, revising, rethinking, and reviewing their ideas about these projects. Ideally, students who complete a WISE project will continue to explore the questions after their science class is over and throughout their lives. For example, teachers report that students return, years later, to discuss new evidence about frog deformities or malaria control. WISE projects instill in students a sense of scientific inquiry so that they can reuse the patterns of investigation when confronted with a new problem. WISE patterns supporting lifelong, autonomous learning take advantage of the inquiry map, prompts, hints, and data analysis tools.

The WISE inquiry map supports autonomous learning by enabling students to carry out projects without having to constantly seek guidance from teachers or peers. In addition, each aspect of the inquiry map including gathering evidence, writing a note, conducting a debate, forming an argument, or graphing data has an icon. As students conduct more and more WISE projects, they encounter each of these inquiry activities under multiple circumstances and in relationship to a broad range of questions. Students see that inquiry steps occur in a variety of different patterns, while at the same time recognizing some common combinations of inquiry steps that occur in almost every inquiry project. Thus, in every project, students look at evidence, write notes, reflect on the connections among the pieces of evidence, and form a cohesive argument. In some projects, students conduct experiments. In others, they analyze data collected by experts, such as climatic, geologic, or geographic information. The inquiry map links these activities and patterns and provides a subtle but consistent reminder that scientific inquiry, while varied, also involves persistent patterns.

WISE projects incorporate a broad range of scientific activities including field trips, visits to museums, observations of creeks and ponds, and analysis of national data archives such as weather information or planetary data. Projects allow students to see these varied scientific activities in the context of inquiry. Teachers report that when students accomplish a series of WISE activities, they begin to recognize how these varied scientific experiences all contribute to inquiry (Slotta, in press). WISE online discussions, debates, and collaborative projects all engage students in scientific discourse and help students understand how scientific discussions take place. Students gain skill in warranting their ideas, in recognizing the perspectives of their peers, and in communicating about scientific material (Linn & Hsi, 2000).

To review WISE projects for their ability to promote autonomous learning, we look for several factors. First we ensure that the inquiry map represents common patterns of inquiry and enables students to recognize methods that scientists use to build reliable understanding and to form cohesive arguments. In addition, we examine the notes that students write when they reflect on their progress. We analyze whether students are gaining an integrated perspective on the project's topic that could be generalized to other topics. We review the selection of examples and applications of a scientific phenomenon to determine whether students will encounter them again in their lives.

FLEXIBLY INTEGRATING NEW TECHNOLOGIES AND TOOLS INTO WISE

In addition to providing designers with built-in features, WISE is designed to integrate new technologies compatible with the scaffolded knowledge integration framework. For example, new JAVA-based simulation tools such as *Agentsheets* (Repenning, Ioannidou, & Philips, 1999) have been incorporated into WISE projects. WISE allows developers to connect these tools to technology supports like the inquiry map, embedded notes, and WISEdraw to support scaffolded knowledge integration. Once incorporated for one project they may be shared with others. For example, the WISE *Causal Mapper* tool (Baumgartner, in press) was originally created to help students describe the factors influencing water quality and now appears in projects related to space explorations, rainforest interactions, and wolf population management. As the original water quality project underwent iterative refinement and other groups began using the Causal Mapper, a promising pattern emerged to overcome initial student difficulties. Initially, students were adding factors but never consolidating or revising the map. To enhance the value of the Causal Mapper for knowledge integration, WISE projects now implement a pattern that includes creating conjectures backed by justifications, conducting experiments, creating a new map based on research, and justifying the new map.

WISE can also scaffold the incorporation of off-line activities, providing a Web-based project context for field trips or hands-on labs. To support these contexts we have begun to research the incorporation of hand-held technologies like Palm Pilots into WISE projects, providing flexible applications for Palm activities and a means of uploading Palm-collected data for whole-class synthesis. WISE scaffolds the use of offline activities, field trips and handheld technologies by providing a project context, a pedagogical framework, and proven curriculum design patterns.

Case Study of Integrating New Technologies: WISE PALM

Probeware and other hand held technologies have been researched as a powerful tool for education (Blumenfeld et al., in press). These researchers have argued that hand held devices can enhance the opportunities for student learning when used for data collection, display of information in the field, and "beaming" information between students using Infrared connectivity. Based on this potential, WISE researchers proposed to explore the integration of Palm activities into WISE (Slotta, Clark, & Cheng, 2002). They received a grant of 450 Palm IIIc devices from SRI's Palm Educational Partnership (PEP) program, and partnered with two large school districts, science discipline experts at the Monterey Bay Aquarium, and other researchers. This work began by incorporating existing Palm activities into WISE projects, such as the "Cooties" application, developed by Soloway and his colleagues at the University of Michigan (*http://hice.org*). We adapted Cooties for the WISE Cycles of Malaria project to help students learn about the mathematics of infectious diseases by having one or two students act as mosquitoes, walking around the classroom "beaming" Malaria to their classmates. In expanding our work with hand held technologies, we partnered with the Monterey Bay Aquarium, to extend and enhance students' fieldtrips by providing an inquiry project to be performed in their science classroom and at the aquarium. Educators from the aquarium wanted to help students focus on marine science concepts, including the factors relating to fisheries decline. We codesigned an activity where students explore the fish in Monterey Bay, reflecting on why some fish are placed on a Seafood Watch List while others are not. Students chose one fish for specialization, which they investigated at the aquarium. Palm Pilots provided students with a means of recording observations about the fish and other features of the aquarium. We designed an observation form that would help students reflect on the habitat and the adaptations of the fish they studied. These observations were then aggregated to form a class data set that was used in subsequent online activities. In future iterations we will test more comprehensive curriculum design patterns for using these technologies.

FLEXIBLE AND CUSTOMIZABLE FOR TEACHERS

In addition to providing flexibility for design teams, the flexibly adaptive nature of WISE enables teachers to customize projects for their own classes. Teachers can add prompts, hints, and glossary definitions easily and enable their students to connect materials to previous classroom experience. One teacher of a Russian bilingual class created special glossary entries for students to distinguish certain English words from their Russian equivalents (Linn et al., 1999). Others have added specific activities on water quality in their region.

WISE projects also enable teachers to customize instruction to their curriculum, computer technologies, and personal styles. Our research reveals that teachers use projects in a broad range of ways. Some complete the project in one or two weeks, while others intersperse the project with activities from the regular curriculum, often enhancing the information students have for debate or design activities (Slotta, in press).

WISE also supports multiple teaching practices because teachers vary in the way they interact with their students. For example, some teachers spend large amounts of time with individual pairs of students and do not get to all the pairs of students in a single class period. Other teachers regularly monitor performance, moving around the class in regular cycles to make sure all students are on task and to make sure individual questions are responded to rapidly. Still other teachers step back and monitor student performance on the computer screen rather than face-to-face. The most effective teacher practices appear to involve a balance of interacting with student groups in long episodes but monitoring performance at regular intervals (Slotta, in press).

WISE projects transform the teacher from a director of inquiry to a facilitation of inquiry. Teachers using WISE have the opportunity to participate in the inquiry activities of their students and to monitor class performance and identify class needs as they arise. This new role for teachers is supported by the WISE software, because teachers can often respond to student questions by saying, “Let’s look at the inquiry map” or “Let’s consider the hints available at this point in the project.” As teachers become more sophisticated users of WISE projects, they often wish to modify the hints and introduce their own pivotal cases into the mix of ideas that students consider (Linn & Hsi, 2000). As a result, WISE projects have the potential, not only for encouraging more autonomous learning on the part of students, but also supporting teachers in their lifelong effort to become more effective purveyors of learning among their students.

DISCUSSION AND CONCLUSIONS

The WISE partnership, using the knowledge integration perspective, has devised ways to create inquiry projects that can adapt to new users and have the potential of sustaining inquiry in science classrooms. Design teams regularly submit projects for library review, and teachers and their students use and customize these projects. As shown in Figure 3, during the year 2000 over 22,000 groups of students carried out library projects. Controversy projects were most popular. Most teachers who start using WISE projects choose to continue using those projects, so projects developed early generally have the most student users over the years.

Design teams have created a broad range of different activities and combined WISE features in many varied and creative ways. At the same time design teams stick to a relatively small set of promising patterns of inquiry that all connect to the basic knowledge integration pattern of identifying the repertoire of ideas, adding new views, and sorting out these ideas. The basic pattern has many variations in WISE projects. Students can identify their own ideas by making predictions, discussing with peers, responding to prompts, or designing preliminary solutions. They can learn new views from visualizations, models, field trips, evidence pages, peers, and experiments. To sort out and connect these ideas students can construct arguments, establish criteria for explanations, compare alternatives, test diverse conjectures, research possible connections, ask for peer review of their work, consult teachers, create representations for their ideas, reflect on alternatives, and revise their work.

WISE enables designers to reuse promising curriculum design patterns by making these patterns visible in WISE library projects. Designers can copy and reformulate whole projects. Library projects feature curriculum design patterns that have been well tested. The first debate project, *How Far Does Light Go*? was used as a pattern for several subsequent debate projects. Over time, developers created and added new patterns and alternatives that succeeded under new circumstances.

WISE offers both proven technology tools and a flexibly adaptive environment for combining the tools with other activities to create promising inquiry projects. Many current WISE features emerged from design team requests and were adapted by other design teams. WISE also supports the trial and refinement process of design teams by keeping track of projects, gathering embedded assessments, and making it easy to revise projects based on classroom feedback. Design teams can analyze pretests, posttests, notes, discussions, and differences between student groups when considering revision.

Both teachers and students can become better critics of scientific materials as a result of engaging in inquiry projects. Nothing could be more important today as the Internet and other media bombard citizens with dubious, questionable, and uncertain scientific information. By offering design teams supports to create projects that engage students in sustained, autonomous inquiry activities where they need to sort out sources of information with varied validity, we increase the number of citizens who become more successful consumers and contributors to the scientific enterprise.

When students and teachers participate in a series of WISE projects, they have the opportunity to gain a deeper and more comprehensive understanding of inquiry because they encounter inquiry patterns in different contexts, under different circumstances, and in different sequences. Students who have completed a WISE project are typically more successful on their second WISE project than those who are doing WISE projects for the first time (Slotta, in press). In addition, teachers become more expert in guiding inquiry as a result of using WISE projects. Thus, when teachers use a WISE project for the second and subsequent time, their students make more gains than they did on the first version (Bell & Linn, 2002; Linn, in press; Linn & Hsi, 2000; Slotta, in press; Williams & Linn, in prep).

To scale research-based curriculum and engage all students in inquiry, WISE offers teachers and curriculum designers a head start. Using WISE projects, features, and curriculum design patterns, combined with a process of trial and refinement makes it possible to customize existing projects, create and test new projects, and monitor progress from one year to the next. WISE continuously adds new, proven features in response to user needs and as a result of user experience. WISE curriculum design patterns capture proven inquiry strategies. These patterns can inform design of other learning environments and of diverse forms of instruction. By comparing WISE patterns to technologies in other successful inquiry projects separated in this issue, we can build a more flexible and comprehensive understanding of effective science instruction. We invite those concerned with inquiry to combine their insights and experiences to build a more robust and cohesive perspective on lifelong learning.

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