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The Web-Based Inquiry Science Environment (WISE): Scaffolding Knowledge Integration in the Science Classroom

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The Web-Based Inquiry Science Environment (WISE) project seeks to extend the Knowledge Integration Environment (KIE) approaches to a wider audience of teachers in a broad range of school settings. Internet technology has developed greatly over the past 5 years with improvements in personal computers, Web browser software, and network access. Building on the foundation of KIE (see Davis, chap. 5, this volume; Bell, chap. 6, this volume; and Hoadley, chap. 7, this volume), WISE has capitalized on these developments to create a second-generation learning environment with improved usability and accessibility for classrooms. New features include a browser-based interface and powerful Web server functionality. Because it is completely Web based, WISE does not require the installation of any software on school computers or servers. In addition, WISE has continued to expand the library of inquiry projects that are available to teachers, supporting an increasing range of science topics and student age groups.

WISE investigates (a) effective designs for inquiry activities and assessments, (b) technology supports for students and teachers, (c) authoring partnerships to create a library of inquiry projects, and (d) professional development programs to enable a wide audience of teachers to succeed with inquiry and technology. In this chapter I describe the WISE learning environment and curriculum partnerships and discuss a research program aimed at helping all teachers adopt inquiry and technology methods.

THE WISE LEARNING ENVIRONMENT

WISE provides an Internet-based platform for middle school and high school science activities in which students work collaboratively on inquiry projects, making use of "evidence" from the Web. WISE projects range in duration from 2 days to 4 weeks, providing inquiry topics for teachers in Grades 4 to 14. Typical projects engage students in designing solutions to problems (e.g., design a desert house that stays warm at night and cool during the day), debating contemporary science controversies (e.g., the causes of declining amphibian populations), critiquing scientific claims found in Web sites (e.g., arguments for life on Mars), and investigating scientific phenomena (e.g., thermal equilibrium). Figure 9.1 displays the WISE student interface, including the pop-up windows for reflection notes and cognitive hints. Students navigate through activity steps in the left-hand frame of their Web browser called the "Inquiry Map." Each step in the project can result in the display of Web pages (to be used in support of student designs or debates), in the appearance of the WISE notes window, an online discussion, or any one of numerous inquiry tools (e.g., Java applets for data visualization, simulations, and causal maps). As the students work through the sequence of activities that comprise the project, the teacher circulates within the classroom, interacting with one small group of students at a time, helping them interpret Web materials, reflect on the topic, and interact with their peers.

The use of Internet materials is fundamental to WISE, and all projects make use of some content from the World Wide Web as well as additional Web pages authored for purposes of the project. In WISE activities, students learn to use the Internet productively for inquiring, critiquing Web sites, designing approaches, or comparing arguments. Each project includes a lessons plan, preassessments and postassessments, links to the National Science Education Standards, a description of the learning goals, and ideas that students will likely bring with them to the project. All student work is saved on central project servers that enable student accounts and teacher accounts to be coordinated. Technology features for teachers include classroom management tools, grading environment, and the capability to make comments that students receive the next time they log into WISE. All of these materials can be seen and activities explored at the project Web site: http://wise.berkeley.edu.

All WISE curriculum and assessments are authored collaboratively using Web-based authoring tools designed as an integral part of WISE. Authors use the curriculum design patterns that have been tested in other projects (Linn, Clark, et al., 2003). Authors develop

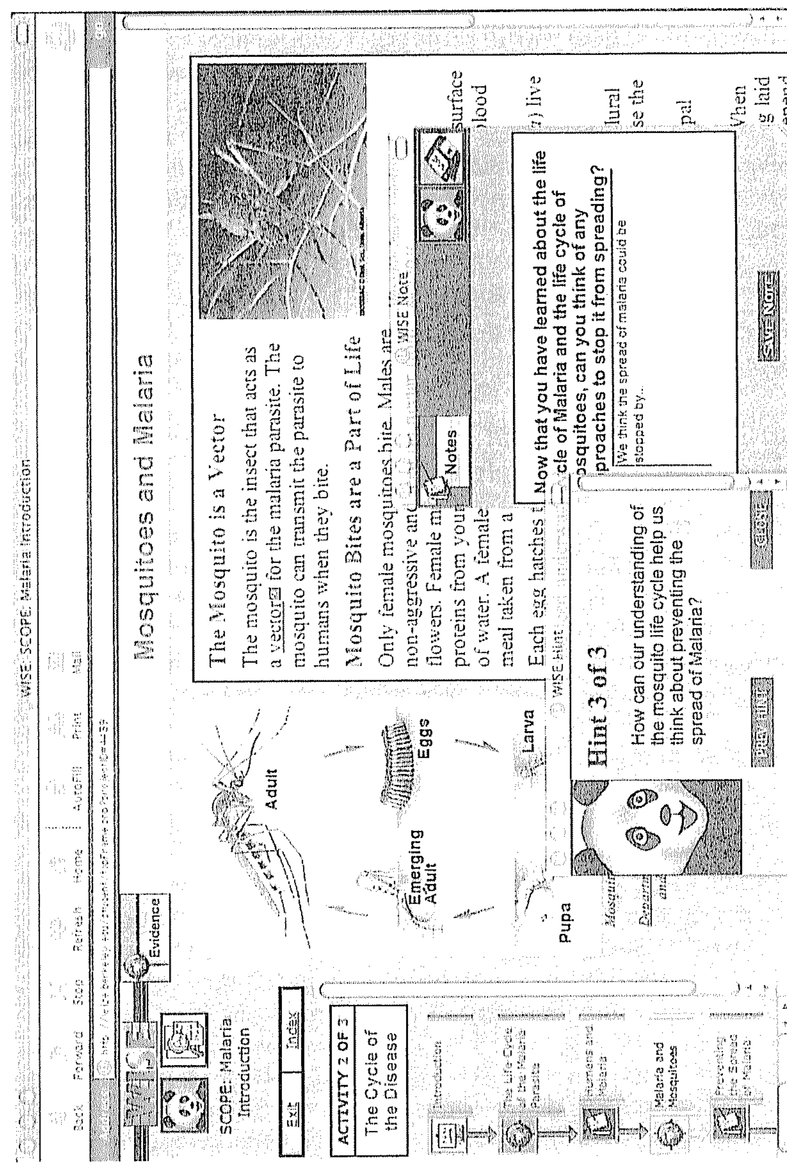

FIG. 9.1. Web-Based Inquiry Science Environment (WISE) student interface showing pop-up notes and hints windows.

support materials for each project, including a detailed lesson plan, preassessments and postassessments, links to the science standards, and a description of the learning goals and the ideas that students may possess at the outset of the project. Teachers access these materials through the "WISE Teacher Portal," a user-tailored Web site that scaffolds their preparation for a WISE project run, their assessment of student work, and their formative feedback to students. Through special links into the authoring software, teachers can even customize WISE projects toward local issues, geographical features, or student populations.

Design Framework for Inquiry Curriculum and Assessments

The WISE learning environment, curriculum, and assessments are all designed according to the scaffolded knowledge integration framework for instruction (Linn, Davis, & Eylon, chap. 3, this volume; Linn & Hsi, 2000). This framework has been continuously refined through years of classroom trials, comparing different versions of technology tools, different approaches to guidance, and different designs for curriculum. The resulting framework thus synthesizes research findings and captures the intricacies of science education in the classroom. By encouraging learners to connect new ideas and perspectives to their ideas about the scientific phenomenon they are investigating, the framework promotes cohesive understanding. Students compare, contrast, critique, sort out, and reconceptualize their scientific ideas incorporating new information, evaluating alternative accounts, and connecting everyday and scientific ideas.

WISE employs a partnership model of curriculum design in which scientists, teachers, educational researchers, and technology specialists collaboratively design inquiry curriculum and assessments (Linn, Shear, et al., 1999; Shear, Bell, & Linn, chap. 12, this volume). Authors also create lesson plans and other resources to help teachers integrate WISE activities into their existing classroom practices. WISE authoring partnerships include science agencies (e.g., National Aeronautics and Space Administration [NASA], National Oceanic and Atmospheric Administration [NOAA], or The National Geographic Society), professional organizations (e.g., The American Physiology Society), and museums (e.g., the Monterey Bay Aquarium) that are committed to developing educational materials related to their scientific expertise. Partners are attracted by the WISE technology, which can deliver the curriculum to a global audience of teachers and students

while providing innovative user supports and professional development programs to enable teachers to adopt WISE successfully. The authoring partners work together to design a pilot project, observe its use in science classrooms, and refine the project based on their observations. Additionally, WISE allows teachers and schools to make their own connections to instruction, incorporate personally relevant problems, link to local science museums or environmental issues, and create custom prompts, hints, assessments, or online discussions.

Science agencies and organizations benefit from the technology features of WISE, which delivers content and functionality to a global audience of teachers and students. More importantly, the scaffolded knowledge integration framework provides a resource for the design of activities and assessments as well as for review criteria to help authors continuously improve their materials. Table 9.1 illustrates how the WISE team has used the tenets of scaffolded knowledge integration to articulate guidelines for the design of inquiry activities. To support and facilitate partnerships, we are currently incorporating such guidelines into our online authoring and review environment.

THE WISE CURRICULUM LIBRARY

WISE partnerships have designed, authored and refined a small library of more than 50 curriculum projects that are currently available in the WISE library. For example, we have formed partnerships with NASA scientists and contractors to design numerous projects including the following: "Rats in Space," in which high school biology students critique the use of rats as models for humans in NASA bone loss studies (Slotta, Dodson, et al., 1999); "Sprouting Space Plants," in which fourth and fifth graders design a terrarium for use on the Space Station Freedom, comparing the growth of NASA space plants with regular earth plants; and "Life in the Universe," in which middle school students evaluate the habitat that might exist on the known planets that have been discovered in other solar systems. In another effort, marine researchers from NOAA and The National Geographic Society have worked in close partnership with teachers and WISE project researchers to create an environmental science project for WISE called "Ocean Stewards," in which high school students design a research expedition to the Marine National Sanctuary that is nearest to their local watershed.

Still other partnerships have been formed with educational research projects that benefit from the existing strengths of WISE, incorporating their own research questions in the design of new

TABLE 9.1
WISE Instruction Framework: Scaffolded Knowledge Integration

Major Tenets	*Design Guidelines*	*Inquiry Activities*
Making science accessible	Project builds on student ideas. Project builds scientific knowledge framework. Students can connect project to personally relevant questions. Project connects to standards-based curricula. Project models the inquiry process. Project ideas are accessible to diverse learners.	Investigating a driving question or inquiry task Eliciting student ideas Connecting to personally relevant problems
Making thinking visible	Students create and use personal representations. Students express their ideas. Students are scaffolded to explore new representations. Students encounter multiple representations. Representations are incorporated into assessments. Activity promotes learning through representations. Activity illustrates the process of inquiry.	Modeling, simulating, animating Graphing, representing data Representing arguments Questioning/explaining Drawing
Helping students learn from others	Activity incorporates different kinds of social activity structures. Students listen and learn from each other. Peers have productive interactions to develop understanding. Students develop shared criteria for scientific discourse. Students have the opportunity to share their findings after generating their own ideas.	Developing criteria Discussing with peers online Discussing with peers in the classroom Reflecting on discussion Conducting a debate Critiquing peers
Promoting autonomy and lifelong learning	Project engages students in meaningful reflection. Project engages students as critics of diverse scientific information. Project engages students in multiple approaches to science inquiry. Project helps students understand and generalize the inquiry process to diverse science projects. Project provides opportunities for learning and applying context-embedded content knowledge.	Writing reflection notes Conducting a project Preparing for a debate Describing an inquiry Critiquing own performance Designing an inquiry Revisiting ideas outside of class

projects. One important partnership involves researchers from the University of Washington and The American Association for the Advancement of Science who seek to develop curriculum based on science controversy. This project, called Science Controversies Online Partnerships for Education (SCOPE; see Bell, chap. 10, this volume), has developed many controversy-based projects including "Deformed Frogs," in which students evaluate competing hypotheses about malformations in North American amphibians (see Shear et al., chap. 12, this volume), or "Cycles of Malaria," in which they critique different strategies for controlling malaria worldwide. These materials offer diverse perspectives that can help students learn to critique materials and appreciate viewpoints.

The WISE curriculum library continues to grow as these partnerships develop new projects and assessments for all age levels and science domains. Additionally, teachers themselves can improve on the curriculum, customizing WISE projects to meet their personal goals and classroom settings. Teachers can use the WISE customization tools to make their own connections to instruction, incorporate personally relevant problems, link to local science museums or environmental issues, and bring current science controversies to life. We made it easy to add relevant Web pages to a WISE project, and create custom prompts, hints, assessments, or online discussions. We have also developed several new online supports for teachers who can share their customizations and annotate projects to share their successful approaches.

TEACHING WITH INQUIRY AND TECHNOLOGY

Even with the support of a learning environment like WISE, the challenges of teaching with inquiry and technology are substantial (see Linn, Davis, & Bell, chap. 1, this volume). For many science teachers, WISE represents a departure from traditional methods such as lectures, textbook assignments, and hands-on experiments.

WISE professional development research is exploring how teachers adopt inquiry and technology methods, how to support them in the difficult first trials, and how their students benefit along the way informed by the scaffolded knowledge integration perspective on instruction. Ultimately, the goal of WISE is to help teachers interact deeply with their students concerning their ideas about science, helping all students develop a personal understanding and a rich experience of inquiry. WISE project researchers investigate the pedagogical ideas that teachers bring to the table as they adopt an innovation like

WISE, including their attitudes about technology and inquiry. Based on observations and interviews of teachers as they implement WISE, we are developing a program that includes workshops, interactions with mentors, and online supports. This program helps teachers customize their science course so that it complements the use of WISE. By helping teachers develop a sense of ownership and control over their use of WISE, we hope to enable them to develop a comprehensive understanding of the pedagogical ideas underlying our innovations.

Teaching With WISE

WISE projects require teachers to interact closely with students as they work in pairs or small groups, supporting autonomous investigations while making complex decisions about allocation of instructional time. Teachers must set up a WISE project run, help students register for WISE, manage their passwords and user accounts, and get them started on the first day with WISE. This includes motivating the inquiry topic as well as explaining the WISE interface and promoting success with the learning environment. Teachers are also challenged to grade student work online as well as to make comments and interact with students during the course of a project. Finally, one of the most difficult challenges in adopting WISE or other inquiry projects concerns the adjustments that a teacher must make for the inquiry project to fit well within his or her existing course. The teachers who have had the best success with WISE have made substantial changes to their course content immediately preceding and immediately following the actual WISE run. Preliminary activities help students develop important ideas that they will draw on in the course of the WISE inquiry unit. Follow-up discussions or activities help them make connections between the WISE unit and the rest of the course. Such adjustments are also more commonly observed in the practice of teachers who have used WISE for several semesters as they exhibit an increasing level of "ownership" of the curriculum (Levey, 1998).

Features of WISE, such as the Teacher Portal, supplemental resources (e.g., lesson plans and preassessments and postassessments), customized comments for students, and online support from the WISE project staff make inquiry teaching more accessible to teachers. The learning environment itself can also help support teachers by making inquiry visible. Teachers can observe students performing the inquiry curriculum and follow students' progress within the project. However, these supports are often insufficient, and most first-time WISE teachers are preoccupied with implementing the technology

and simply surviving the day. The opportunities offered by WISE for interacting with students concerning their ideas about science are often lost amidst the flurry of new challenges in simply getting WISE to run successfully with their class.

Ideally, professional development must help teachers interpret new inquiry practices in terms of their prior instructional methods. For example, in contrast to prior textbook-based methods that completely excluded science controversy and source credibility, WISE critique activities may expose students to biased, incomplete, or erroneous information. Other new practices will be concerned with student collaborations such as learning to focus on those students who are experiencing difficulties whereas enabling the others to remain on task.

We have designed a model of mentored professional development that incorporates the knowledge integration perspective on learning about inquiry instruction (Linn, Eylon, & Davis, chap. 2, this volume). Professional development can address the interpretive nature of science instruction by helping teachers identify some of their own ideas about inquiry and seek pivotal cases to understand how inquiry could fit into their practice. We address the deliberate nature of science teaching by helping teachers customize WISE curriculum and adopt a tailored lesson plan for their own science course. We address the cultural aspect of science teaching by connecting teachers in collaborative activities and by including a WISE mentor who helps model new practices and provides careful feedback throughout the process.

The WISE Mentor Model

WISE mentor model of professional development helps teachers develop a cohesive understanding about inquiry instruction by building on their existing ideas about student learning, technology, and the role of the instructor. Following the four principles of the scaffolded knowledge integration framework for instruction, we make inquiry visible through visits to a mentor's classroom where WISE is being run and through workshops where videotape of WISE master teachers is discussed. We make ideas about inquiry accessible by helping teachers compare their own practice with that of the mentor who models the use of WISE in the teacher's own classroom. Additionally, our workshops focus on helping teachers reflect on the challenges of adopting WISE and creating a lesson plan for the successful incorporation of a WISE unit into their overall curriculum. We provide social supports for teachers using WISE with peer networks and mentor relationships. Finally, we encourage autonomy by engaging teachers in customizing WISE lessons based on their experiences, scoring student work according to WISE scoring standards, engaging in iterative refinement of their instruction, and reflecting on the reasons for any customizations.

Ultimately, when teachers feel a sense of ownership of the curriculum and confidence in how it is meeting their goals for student learning, they will be more successful and more likely to customize and improve on the innovations (Songer, 2000). A WISE mentor facilitates this process, scaffolding new teachers as they (a) explore the WISE technology and choose an appropriate project and (b) plan how that project will fit into their existing course curriculum or how they might alter or rearrange their syllabus to help make the WISE project a better fit. After this planning stage, the mentor helps the teacher succeed in his or her first WISE run. Even though WISE is technologically straightforward and easy to use, many teachers benefit from reassurance, support, and demonstrations. The mentor demonstrates how to help students register in WISE, how to conduct an initial discussion of the WISE project with their students, and how to lead the class through the project, balancing in-depth interactions with individual students and whole-class discussions. In subsequent stages of the model, the mentor continues to be involved, helping the teacher learn to use the online assessment and feedback tools and eventually to customize a WISE project using the authoring environment. In subsequent semesters or school years, the mentor helps the teacher plan his or her curriculum more deliberately to build around the use of WISE, ultimately leading to a smooth integration of the WISE technology and inquiry curriculum. Finally, the mentor tries to enable the development of a community of peers within the teacher's school who are all involved with WISE, with the goal of establishing an ongoing professional development network concerned with science inquiry and technology.

We have investigated this model in diverse settings including whole-school studies and district-wide scaling initiatives. Teachers often are bound by logistical constraints (e.g., time within their syllabus and access to technology resources) and are motivated by a wide range of factors (e.g., the ideal technology innovation for some teaches is one that can stand alone without their involvement). WISE curriculum, which focuses on depth coverage of specific topics, presents a challenge to school districts that are striving to meet a breadth of content standards (Krajcik, Marx, et al., 2000). These districts often evaluate programs based on their impact on students' achievement on standardized tests. Whereas the most effective way to improve student performance on such tests is to directly target the test topics in short term regurgitation of facts, WISE is focused on establishing lifelong learning skills and promoting autonomous understanding. The success of WISE within a school and district setting depends on a variety of factors concerned with the teacher, the school science department, technology resources, and the school district science curriculum policies. Our goal is to develop a successful model of mentoring that is somewhat tolerant to these factors, enabling a wide audience of teachers to succeed with WISE and helping promote forward progress in how schools and districts incorporate technology and inquiry into their science curriculum.

A WHOLE-SCHOOL STUDY OF THE WISE MENTOR MODEL

We began a whole-school study in a middle school where none of the six science teachers had any experience with WISE nor with computer-based instruction. This study included a mentor who worked closely with each teacher as they worked through the various stages of running a WISE project: preparations, use of WISE in the classroom, and assessment of student work. The mentor helped the teachers customize their course curriculum to make the WISE project a better fit. During a teacher's initial use of the project, the mentor modeled effective inquiry instruction during the first period of each day, allowing the teacher to take over in subsequent periods. This allowed teachers to observe the mentor's approach and also freed them to interact with students right from the start. On completion of the first WISE project (usually lasting between 5 and 10 school days) the mentor facilitated assessments and helped the teacher use the online grading system (a feature of the WISE teacher portal). The mentor also tried to raise the level of student–teacher interactions from procedural guidance to a deeper level of integrated understanding about student inquiry. After all six teachers had cycled through the computer laboratory in this way, they prepared for their second WISE project. During this second WISE project run, interactions between mentor and teachers were greatly reduced as the role of the mentor shifted to one of careful observations and feedback.

By the end of this 2-year study, the mentor's presence had completely faded with no further interactions required by the teachers. One measure of teacher success was the pretests and posttests of student understanding as well as embedded assessments of student project work (e.g., their WISE notes and arguments). Another was the teacher's ability to continue running WISE autonomously and their interview reflections over the course of this study. Differences in teaching style were examined, and student outcomes were compared in terms of their sensitivity to the depth of teacher–student interactions and the coherence of the curriculum plan. We also explored how different teachers interacted with the mentor to determine what kinds of feedback were helpful to teachers who held various ideas about technology, inquiry, and science learning.

Teacher–Mentor Interactions

The mentor was heavily involved in each teachers' first classroom trial of WISE but gradually faded his involvement as the first year progressed. Initially, the mentor helped by modeling WISE instruction for teachers. As there were six periods in each school day, the mentor could demonstrate in the first period how to introduce WISE to students, how to help them register, and so on. By the end of that day, however, the teacher was leading each period and the mentor was observing and offering feedback between periods. When the first WISE project was complete, usually lasting between 5 and 10 school days, the mentor assisted in the postassessments and then helped the teacher learn to use the WISE online grading system. At this time, the mentor also provided feedback to the teacher concerning his or her interactions with the students and with the class as a whole. For example, one teacher was advised to stop the class more frequently and focus all of the students on a short verbal question or discussion. Occasional pauses or interruptions like this can be quite helpful, as they enable the teacher to provide a broadcast feedback to the class based on observations and interactions with students. As one teacher neared the completion of his or her first WISE project run, the next would begin preparations with the mentor, then begin using WISE once the previous teacher was finished with the computer laboratory.

After all six teachers had cycled through the computer laboratory in this way, they prepared for their second WISE project. Once again, the mentor conferred with each teacher to help select an appropriate project for their course and to help adjust the curriculum activities immediately preceding and following the WISE run for purposes of continuity. During the WISE run itself, however, interactions between mentor and teachers were greatly reduced, in some cases to "on demand" only. The role of the mentor shifted to one of careful observations of the individual teachers who felt that they were really demonstrating their new skills in this second WISE run. After each day of the run, the mentor conferred with the teacher to give feedback on the nature of

questions asked to students, the flow of whole-class and small-group interactions, and the ideas that students were exhibiting in the project. In this way, the mentor tried to raise the level of interactions from procedural guidance to a deeper level of integrated understanding about student inquiry.

As the first year came to a close, only one of the teachers felt unable to continue using WISE in his curriculum primarily because he could not find a project that fit his particular course syllabus to his satisfaction. At this point in the study, it was clear that teachers differed in their abilities to use WISE autonomously, in their level of comfort in working with students, and in their commitment to integrating inquiry and technology within their course. I discuss these differences in the next section. In general, we were encouraged by the progress exhibited by all six teachers in the school and by their growing level of autonomy. As the second year of the study began, all five returning teachers were well prepared to run WISE. They had thought in advance about the topics they would teach and how the WISE units would fit within their syllabus. In addition, they had begun to interact with one another regarding issues of scheduling the laboratory, and at times they even discussed issues of student learning and their own teaching practice. During this year, the mentor was not present in the school for most of the time. He met with each teacher briefly at the beginning of the semester to help plan their use of WISE then met with them once again just before their WISE project run began. At least once during the first semester the mentor observed the teacher and gave feedback on their student interactions at the end of that session. Midway through the second year, the mentor completely removed himself from the setting and kept in touch with the teachers only as necessary. At this point in the study, the five teachers were truly autonomous and were using WISE enthusiastically as a department. Even the sixth teacher who had excused himself returned at the end of the year to inquire about authoring or customizing a WISE project that better matched his curriculum.

Differences Between Teachers

Although the discussion following focuses on the differences between two 7th-grade teachers, the six teachers were all seen to vary in the nature of their interactions with students as well as their flow of activities within a class period. Several of the teachers struggled with the misinterpretation of WISE as a "teacher-proof" computerized activity that students guided themselves through. Quite to the contrary, the classroom teacher is an essential part of the equation in fostering student inquiry. However, one teacher was even heard to utter, "This is great! I can just sit here and grade papers." Helping teachers revise such early conceptions of WISE was one of the more difficult matters for the mentor to address. Several of the teachers persisted in the belief that if the students are quiet and engaged, they do not need to be bothered, and the teacher can just make sure nobody is having any problems. The mentor responded to these ideas by trying to express the value of teachers playing an active role in student inquiry and how WISE offers teachers the opportunity to do so by scaffolding the class as a whole.

Teachers varied in the depth of their interactions with students as well as in the frequency of their whole-class interactions. Some teachers engaged deeply with individual students for several minutes at a time, whereas others cycled quickly through the class, stopping at each computer for just a second or two to check in on students' progress. One teacher interacted with students at such a deep level that she literally ignored the class as a whole, trusting that WISE was occupying them but never addressing the whole class. Another teacher addressed the whole class so frequently that students could never become truly focused on their project work. In general, such interactions are quite difficult to balance, and the majority of the mentor's feedback to teachers was in this area of expertise. Overall, it was found that teachers did not observably change their styles—those who were highly interactive remained so, and those who were hands off remained hands off. Given feedback from the mentor, however, each individual teacher was able to adjust within their own style to improve their interactions with students.

SANDRA AND GILBERT: COMPARING SEVENTH GRADE LIFE SCIENCE TEACHERS

Two teachers in particular make an interesting case study for comparison because they teach in the same grade level (seventh), the same area (life science), and because they chose the same WISE projects to use in their courses. These teachers, pseudo-named Sandra and Gilbert, are also interesting because they differ quite dramatically in their inquiry practices. Our earliest interviews revealed that they approached their classes with different teaching styles and had different ideas about teaching with inquiry and technology. Although both are mature teachers with at least 5 years' experience in their school, neither proved exceptionally successful in using WISE on the first day, and we observed dramatic differences in their interactions with students. Interactions with the mentor also differed, leading to differential improvements in their professional development with WISE during the first and second years of the study. We chose these two teachers for the comparison study detailed following because they exhibited ideas about teaching and learning that are common to many teachers and because they both ultimately succeeded with WISE, drawing on different aspects of the mentoring and technology supports provided within this study.

Sandra is a veteran teacher with more than 10 years experience who prefers hands-on laboratories and loves to work closely with her students in small groups. Her life science course focuses on topics of animal and plant biology in close connection with the California state standards and a textbook chosen by her school district. She has traditionally made use of many hands-on laboratories in which students work individually or in small groups dissecting worms, examining cells under microscopes, and weighing plant material before and after different procedures. Many of her curriculum laboratories have been discovered at meetings of science teachers or through professional magazines. Sandra can be described as technology shy in the sense that she never used computers in her class curriculum and was unfamiliar even with her own classroom computer. Critiquing WISE, she commented on how it is difficult for her to read things from the computer screen and likes to have printed materials to grade. She was enthusiastic, however, about the connections that WISE projects make to current topics (e.g., the deformed frogs issue) and to materials on the Web. She was also excited about the use of science controversy as a source of curriculum and chose the Cycles of Malaria project and the Deformed Frogs projects partly for this reason.[1] Sandra insisted that she could never adopt WISE without the close assistance of a mentor and was highly receptive to feedback from the mentor, often soliciting advice.

Gilbert has less teaching experience than Sandra, although as chair of the science department was more involved in the details of this whole-school study and saw himself as a leader. His teaching style can be described as traditional with a focus on controlling the class and an authoritative role with his students. His syllabus was quite similar to that used by Sandra, as the two plan their curriculum together each year. Although Gilbert uses many of the same laboratory activities, and his classroom is filled with animals in cages and science toys, he devotes more time to lecture in his curriculum than Sandra, and his hands-on activities are characterized by a higher level of orderliness and control. Gilbert is slightly more technology savvy than Sandra, although he had never used technology in his instruction and rarely used his classroom computer except for a computerized grade book. He was enthusiastic about WISE because of its promise to bring an innovation to his department that would help to integrate technology into science instruction—a district-wide goal that was far from achieved within this particular school. Although Gilbert appreciated the achievements of the WISE mentor (who was a retired master teacher) and spoke to the importance of mentoring and professional development, he seldom interacted with the mentor and never sought advice on teaching with WISE.

To begin the year, all six teachers completed the WISE workshop, as well as a short 2-day WISE project called "Life on Mars" in which students explored evidence on both sides of a claim about a recently discovered meteorite from Mars. This short preliminary project served to introduce WISE to the students, helped get teachers and students registered, and allowed the mentor to model effective inquiry instruction. After all six teachers had run through the workshop and Life on Mars, they each ran a more substantial WISE project guided by the mentor as described previously. Both Sandra and Gilbert chose Cycles of Malaria for their first WISE project because it corresponded topically with their treatment of disease vectors. In the second (spring) semester, they both ran the WISE Deformed Frogs project because of its focus on science controversy and topical relevance. In the second year, they ran the same two projects again, which enabled us to contrast their practices as well as their student achievements. Because Cycles of Malaria was the first WISE project that was led by these two teachers (Life on Mars was quite short and led predominantly by the mentor), it provides a good lens into their inquiry teaching practices and the results as measured by their students' success on WISE assessments. We observed Sandra and Gilbert as they taught the WISE Cycles of Malaria project, carefully coding interactions with students and mentors and interviewing them before and after the project run. We analyzed student work in this project, using both preassessments, postassessments and embedded assessments that focus on knowledge integration measures. Because these two teachers ran the project again in the second year, we were able to look for indications of progress, particularly as reflected in student assessments. We can address any differences between the two teachers initially and then compare their progress. In the next section, I detail the Cycles of Malaria project and how students are assessed.

The Cycles of Malaria Project

In the Cycles of Malaria project, students debate three different approaches for controlling malaria worldwide: (a) developing of an effective pesticide that targets the anopheles mosquito, (b) developing a vaccine against this disease, and (c) creating social programs that reduce exposure to mosquitoes (e.g., through distribution of bed nets or community clean ups). Students explore evidence relating to each control method and debate alternative approaches. Teachers in middle and high school biology and advanced placement biology have used the project. To make thinking visible, the project includes animations and video of the mosquito and parasite lifecycles as well as maps showing the worldwide incidence of malaria. To make the science debate accessible to students, we included the story of Kofi, an African child suffering from malaria, and teachers often made connections to more personally relevant diseases in North America (e.g., HIV or sickle-cell anemia). The project promotes autonomy and lifelong learning by encouraging students to compare scientific viewpoints, evaluate conflicting recommendations, and reflect on personal travel decisions. To learn from others, students discuss their ideas with peers and engage in class debates. Pivotal cases that help students learn about malaria include comparisons between countries choosing to control use of DDT with those discontinuing use. In these pivotal cases students look at both infant mortality rates and data on the size of bird populations. They use this pivotal case to interpret arguments in legislation calling for a global ban of DDT.

To customize Cycles of Malaria, middle school biology teachers included field trips to local ponds or puddles to collect mosquito larvae. More important, teachers were observed to practice various methods of integrating the WISE curriculum with their existing materials and syllabus. For example, a high school chemistry teacher elected to focus on the chemical compounds within the DDT pesticide and how they impact the environment. In this way, teachers in diverse settings and topic areas can provide their students with a meaningful implementation of the Cycles of Malaria project.

WISE Assessments: The Cycles of Malaria Project

WISE preassessments and postassessments challenge students to reflect and respond to complex problems. For example, before and after Cycles of Malaria students are asked to apply concepts of vaccines, life cycles, and disease vectors to novel situations and to solve problems relating to travel and medical research. Students also evaluate applications to personally relevant situations (e.g., traveling to a foreign country) and transfer of ideas to novel situations (e.g., advising a small country on a pending law to clean up standing water around all rural villages). Two example items are presented following with sample student responses. These responses are coded and scored in terms of the number of connections made by students to other ideas and experiences as well as for any causal explanation that is contained within the response. Such coding allows for a wide range of student achievement on each item:

> Preassessment and postassessment Item 1:
> A country is planning a law that would fine people for letting puddles or buckets of water stand around their property. Would this law slow down the spread of malaria? What is the main reason for your answer?
> Example student reflections:
> Yes this would slow the spread of malaria because it would keep mosquitoes away from the towns and make people clean up their mess [student with limited connection and missing or incorrect causal account].
>
> Yes, this would be a good law, because mosquitoes lay their eggs in puddles and buckets, so banning those would mean fewer mosquito larvae [student with substantial connections and accurate causal explanation].
>
> Preassessment and postassessment Item 2.
> What advice would you give to a friend who is planning a trip to a country where malaria is common?
> Example student reflections.
> I would tell him to keep away from people with malaria, always wear a face mask, and take a vaccine before he goes [student with limited connections and erroneous causal account].
>
> I would say, always wear bug spray and keep inside at dusk when all the mosquitoes are coming out. Also, sleep under a bed net at night [student with accurate causal account and substantial connections].

Preassessment and postassessment items are coded for connections, correctness, and coherence of explanations and arguments. Wearing a face mask (the first student) might be a connection to a health-related idea, but it is an incorrectly held idea (face masks do not prevent malaria) and is incoherent, as it is not causally connected to the explanation.

Embedded assessments used within WISE projects include reflection notes, online discussions, drawings, causal maps, and graphically outlined scientific arguments, among others. These assessments provide a measure of the project's impact on student understanding, providing helpful feedback to partnerships concerning their designs, to

our research studies, and to teachers concerning the ideas held by students throughout the activity. Reflection notes can be coded by researchers in terms of the connections students make to ideas within the project, the course, the news, or everyday experiences. In Fig. 9.2 following, students reflect on the dilemma of using the "Miracle Insecticide" DDT and whether it should be banned globally.

> We think DDT is a dilemma because it kills the mosquitoes but also harms the environment. So nobody can decide whether DDT should get used or not [student reflection with few connections].
>
> DDT was on the verge of wiping malaria off the Earth until Rachel Carlson published her famous novel *Silent Spring*. Then it was discovered that birds' egg shells were becoming too thin, as well as other environmental problems. So countries stopped spraying DDT and the environment began to recover, but so did the mosquitoes that carry malaria [student reflection with substantial connections].

These two examples illustrate how student reflections contain varying levels of connection to other ideas, concepts, and experiences. These reflections are coded to obtain a connections score for each student reflection note, which can then be used in analyses of student or teacher progress as described in the following sections.

Sandra and Gilbert: Inquiry Practices

We contrasted the adaptations of Cycles of Malaria made by Gilbert and Sandra in their first run of this project, focusing on curriculum adjustments, classroom presentation, and student interactions. The mentor had facilitated in their preparation for this project, although their unfamiliarity with WISE and with the specific content of Cycles of Malaria made it difficult for the teachers to adjust their overall curriculum effectively. Thus, the overall impression reported by both teachers during interviews was that the project did not fit well within their syllabus, and it was a stretch to make connections to the disease topics covered prior to the project. Neither teacher implemented any curriculum topics following WISE that would lead to further connections by their students. In general, the teachers both expressed some frustration at their inability to integrate WISE within their curriculum.

In their classroom presentation of WISE, the teachers made great efforts to emulate the model that had been demonstrated by the mentor. The mentor's style, developed over several years of efforts with WISE and previously with KIE and Computer as Learning Partner, in-

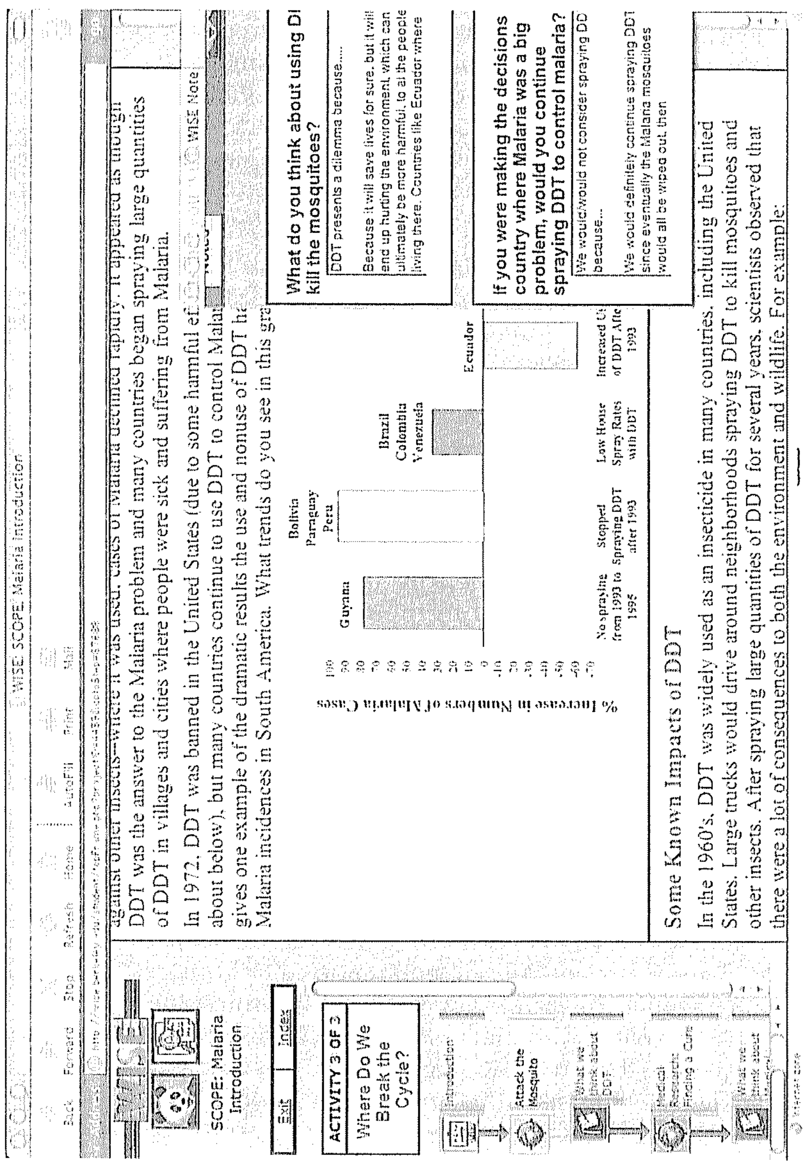

FIG. 9.2. Students' reflection.

volves a somewhat delicate blend of whole-class lecture, elicitation of student ideas, question and answer, and demonstration. Although Sandra and Gilbert made efforts to achieve a similar style, the results of their efforts were at times quite disparate from the model. In essence, both teachers added their existing style to the equation, knowing no other way to teach. This resulted in a fairly strong lecture component from Gilbert and a more interactive style from Sandra. The two styles differed markedly from that of the mentor, and observers frequently worried that students were not getting some of the important messages. For example, in introducing WISE, the mentor often coordinates a class discussion concerning the nature of scientific versus courtroom evidence and how the World Wide Web can be used as a source of evidence for one's arguments and designs. This leads to a discussion of critical evaluation in terms of source authority implicit motivations by Web authors. Such discussions were missing from Sandra and Gilbert, who struggled through the basic process of just getting their students logged on and working within WISE. Apparently, the challenges of implementing a new technology and curriculum innovation required some level of triage by teachers in terms of meeting the bottom line of getting students engaged with the program.

We carefully observed teacher interactions with the students, counting the number of separate occasions when a teacher stopped to discuss the WISE content with a pair of students. Many of these teacher–student interactions were focused on the science content, which was an area in which the teachers felt they had some strength. Some interactions were concerned with the WISE technology or with the nature of the inquiry task (comparing three different control strategies for Malaria). Generally, the length of a student–teacher interaction correlated with its depth. When a teacher paused only briefly at a pair of students' computer, the interaction was typically meant to just check in on them, see what they are doing, or let them know they are being watched. In contrast, more protracted interactions were generally focused on the inquiry topic. To even the casual observer, it was obvious that Gilbert preferred more cursory interactions, whereas Sandra engaged in lengthy discussions that could go on for several minutes. Indeed, a qualitative difference between the two teachers became quickly apparent, as Gilbert was usually seen constantly circulating among his students, making sure that everyone was on task, and Sandra was usually seen interacting deeply with one pair of students or another. This difference, illustrated by Fig. 9.3 following, led to separate concerns about the progress of students in each teacher's class. For Gilbert the concern was that students would miss out on the important aspects of teacher as a learning partner. For Sandra's class the concern was that she was spending too much time in personal interac-

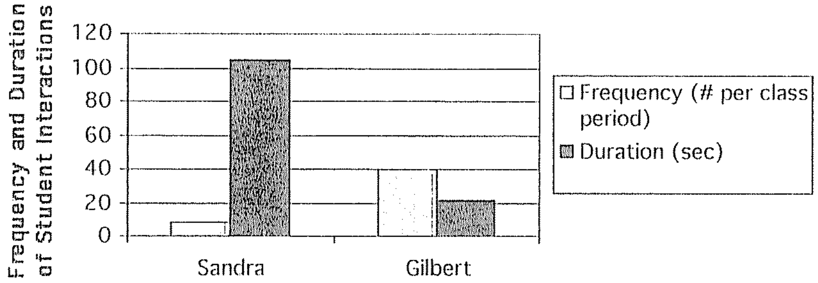

FIG. 9.3. Gilbert and Sandra varied greatly in the frequency and duration of their interactions with students who were running a Web-Based Inquiry Science Environment project.

tions with the students and never pulling back to summarize or synthesize her impressions.

Sandra and Gilbert: Student Learning

We explored the impact of the observed differences in teacher–student interactions by examining student work in the project. It seemed likely that such noticeable differences in teacher practice would be reflected in student work on the projects. To our surprise, however, there were no significant differences in students' scored responses to these pretest and posttest items, as shown in Fig. 9.4. Apparently, WISE Cycles of Malaria was fairly tolerant of differences in teaching styles, as students in both classes made significant pretest and posttest gains, $F(1, 162) = 182.9$, $p = .0001$.

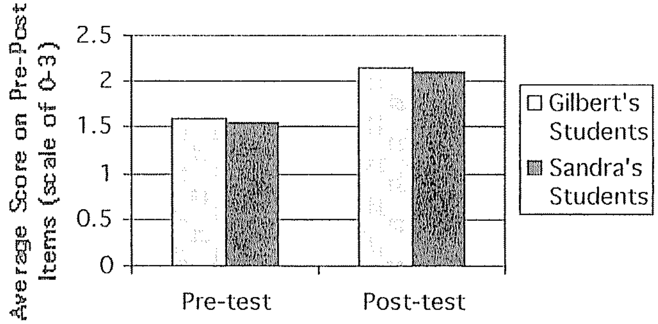

FIG. 9.4. Students of Gilbert and Sandra showed nearly identical pretest and posttest score gains, suggesting that Web-Based Inquiry Science Environment "Cycles of Malaria" project is somewhat robust to teacher differences.

In further investigating the possible impact of teacher differences on student achievement in WISE, we performed a more detailed analysis on the individual pretest and posttest items to look for possible differences between students in the two classes. Within the six-item test, three of the items were more focused on content-specific details. For example, Item 1 asks students, "How can I catch malaria?—a) by kissing, b) by mosquitos c) through shared needles d) by coughing." In contrast, the other three items were focused on knowledge integration, designed to challenge students as they apply the ideas within the project and extend their understanding. For example, Item 4 asks students what advice they would give to their friend who was planning a trip to a country where malaria is widespread.

The six test items are shown in Fig. 9.5 (collapsed across pretest and posttest scores), with Items 1 through 3 as the three content-focused items and Items 4 through 6 as the three knowledge integration items. Apparently, WISE assessments were sensitive to variations in teacher practice, as Sandra's students are seen to have an advantage over Gilbert's in the three knowledge integration items. Interestingly, Gilbert's students illustrated a greater attention to detail with a slightly better performance on the more factual items. In a repeated measures analysis of variance, this interaction of test items with teacher is significant, $F(5, 810) = 11.5$, $p < .0001$.

Another measure of the impact of teacher differences on student understanding is found in students' performance within the WISE project itself—particularly in the reflection notes taken by students during their WISE project work. These notes can be analyzed as de-

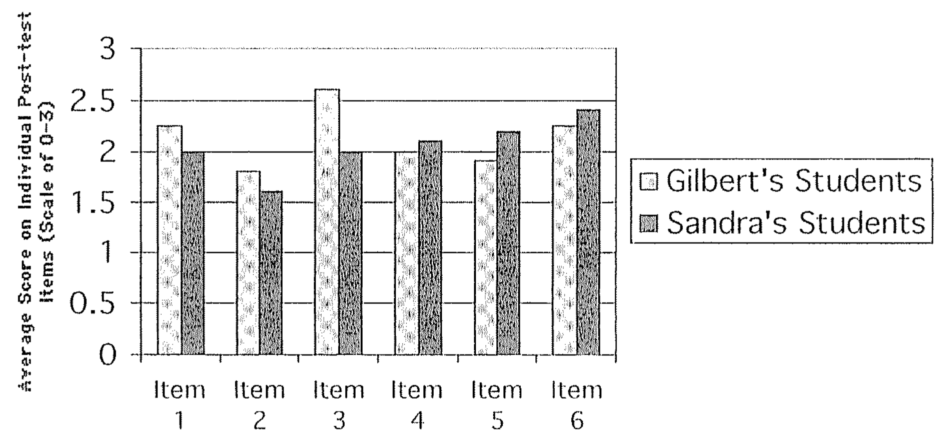

FIG. 9.5. Comparison of scores on "Cycles of Malaria" project posttest show Sandra's students significantly outperform Gilbert's students on most conceptually challenging items.

scribed previously, coding each note in terms of the connections made by students to other ideas or content within the project. For example, when asked to reflect on the merits of developing a vaccine, a pair of students working together in Sandra's class observed the following (with connections underlined):

> We think that developing a vaccine is a good idea because it could create for the body an immunity in which people would not be infected by the parasites, even if they were bitten by an already infected mosquito. Also, it would be easy to make, easy to transport, and does not effect the environment. The overall price of the vaccines would also make the poorest countries be able to afford them. However, some of the problems with this solution are that scientists have not yet been able to create a really effective vaccine, although there was a vaccine in England that used DNA to prevent from getting infections such as malaria, it wasn't as effective as it needs to be. Scientists also are afraid that introducing new DNA may cause cancer for some people.

When such reflections were coded for a set of WISE notes, it was found that the two teachers' students differed dramatically in terms of the number and the coherence of connections they made within their reflections. For example, one pair of students working in Gilbert's class responded to the same prompt for reflection in the following way, with connections underlined: "We think that developing a vaccine is a good idea because it could protect everyone from the disease. However, some of the problems with this solution are it would take a long time and it would be very expensive." There were certainly students in Sandra's class who were less reflective and students in Gilbert's class who were more reflective than these selected examples. However, Fig. 9.6

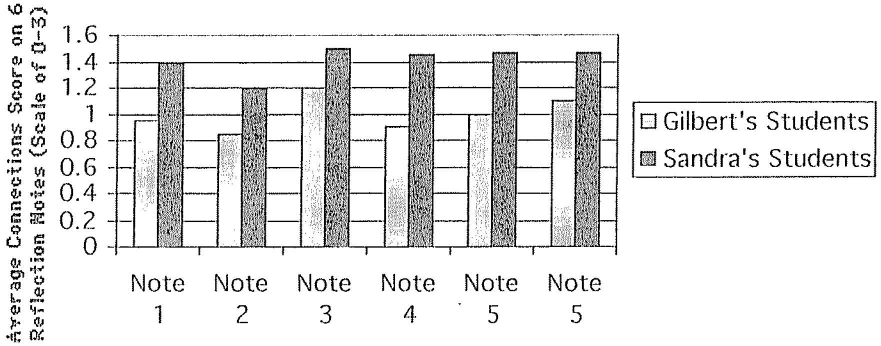

FIG. 9.6. Sandra's students are seen to reflect more deeply, making more connections to ideas within their embedded assessments than Gilbert's students.

shows dramatic overall differences between the students who worked on WISE in these two teachers' classes. Apparently, Sandra's depth of student interactions resulted in far more substantial reflection by her students than the relatively superficial interactions that Gilbert preferred.

Sandra and Gilbert: Comparing Progress from Year 1 to Year 2

In the second year of this study, both Sandra and Gilbert ran the Cycles of Malaria project again, allowing us to compare their efforts in the first and second years. From the start it was clear that the two teachers had made notable improvements in their use of WISE within the classroom. The benefit of having run this project before and the resulting comfort with WISE allowed the teachers to focus more on communicating with students about the science and inquiry processes. Additionally, both teachers were able to make substantial adjustments to their curriculum in this second year, adding a new focus on tropical disease that allowed them to foreshadow the Malaria project and provide greater context for their students. In interviews, both teachers said that one of the most important differences between Year 1 and Year 2 was the opportunity to tailor their curriculum so that it would complement the WISE materials. However, there remained observable differences in the style of interactions with students. Not surprisingly, both teachers retained their basic styles from one year to the next, with Sandra still preferring to spend most of her time working closely with one pair of students at a time and Gilbert preferring short, procedurally focused exchanges with students. Both teachers made some improvements, however, with Gilbert making greater efforts to communicate with his students about their science understanding and Sandra making an effort to pull back from one-on-one interactions and address the whole class.

Figure 9.7 shows the connections scores on student reflection notes in the teachers' first and second run of the WISE Cycles of Malaria project. Although differences between Sandra and Gilbert remained significant in Year 2, $F(1, 117) = 32.22$, $p < .0001$, both teachers made significant gains in this measure. In interviews following this second run, both Sandra and Gilbert described a much greater sense of ownership of the curriculum, a much higher comfort level with the technology, and a greater integration of WISE within their curriculum. Although some differences in classroom practice remained between these two teachers, the pattern of data shown in Fig.

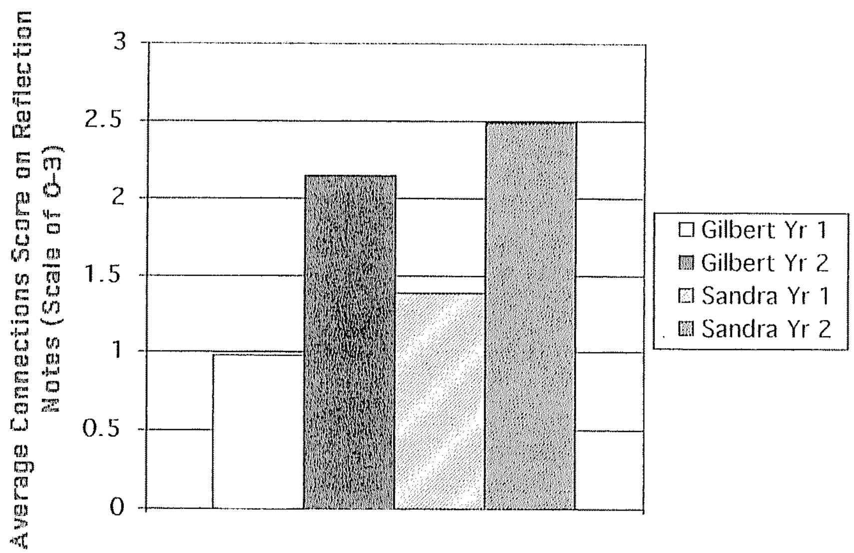

FIG. 9.7. Both teachers improved markedly from Year 1 to Year 2 in terms of their students' connections in the embedded assessments. The difference between the teachers is still present but diminished.

9.7 suggests that the WISE technology and mentoring process was able to scaffold their interactions with students, leading to a much richer set of student reflections. This result is satisfying given the fact that the WISE mentor had faded from the classroom completely during the second year of this study.

Conclusions From the Study of Sandra and Gilbert

This study has helped illustrate how diverse teaching approaches influence student learning outcomes and how curriculum designs can meet the needs of diverse teachers. It also demonstrated that WISE embedded assessments are sensitive to teaching style, as classes from the two teachers differed in their patterns of learning gains. The WISE Cycles of Malaria project was adopted successfully by Sandra and Gilbert, who had similar seventh grade life science curricula but quite different teaching styles. In the first WISE project run, the mentor was quite important to both teachers' success, and WISE proved to be robust in the sense that students in both classes showed evidence of knowledge integration as measured by preassessments and postassessments as well as embedded assessments. WISE professional development was also seen to be successful, as both teachers improved in their use of WISE from one year to the next, even with the fading of the mentor. This improvement was measured by the embedded assessment of coded reflection notes.

As a result of this study, we have gained important insight about the need for mentor participation, the role of WISE technology in the classroom, and the progress of teachers from one year to the next. We have continued to improve our support technologies for teachers in the classroom, our methods of dialoging with districts and school science departments, and the kinds of interactions we encourage between the mentor and the teacher. Additionally, we are continuously improving our WISE planning guides for teachers to create a customized lesson plan around a WISE project, including activities to precede and follow on the WISE unit itself. Through such research, we are also able to implement and observe the WISE curriculum and assessments in a much wider range of contexts, allowing us to improve our materials, support more diverse customizations, and document student learning gains.

FUTURE DIRECTIONS

WISE has proven to be an effective framework for inquiry curriculum in a broad range of science topics and student age groups. The study reported here suggests that WISE can accommodate teachers with diverse perspectives and styles while still preserving the desired inquiry experience for students. Our professional development model is well suited to implement in school district partnerships. Moreover, our authoring partnership model can support a wealth of different curriculum collaborations. This flexible foundation has given rise to several promising projects that I review in this section. In the SCOPE project, WISE provides the student learning environment technology platform and the pedagogical framework for partnerships of scientists to develop curriculum projects relating to current science controversies (see Bell, chap. 10, this volume). Another collaboration has been with the Synergy Communities For the Aggregation of Learning about Education project whose investigators are exploring how diverse educational research efforts can share their findings, materials, and technologies (see Baumgartner, chap. 11, this volume). WISE researchers are currently partnering with several other research groups who are developing new tools for water quality curriculum that run on the Web and hand-held devices (Slotta, Clark, et al., 2002).

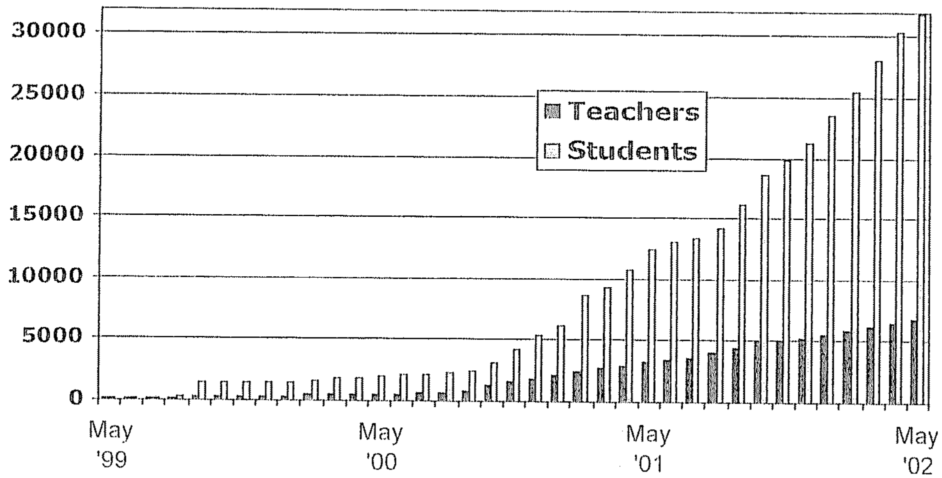

FIG. 9.8. The number of Web-Based Inquiry Science Environment teachers and students over the past 3 years.

The number of teachers and students who have performed WISE projects has grown dramatically over the past 3 years (see Fig. 9.8). Although this growth demonstrates the ease with which motivated teachers can implement WISE, many of these teachers deserve mentoring to help them use WISE to its fullest advantage, and typically they lack support from their school or district. We must research the necessary professional development for scaling beyond these "maverick" teachers (Songer, 2000) to establish WISE as a scalable innovation for science instruction in whole schools and districts.

Building on the study described in this chapter, WISE has formed partnerships with several school districts to research the adoption of technology and inquiry innovations within a systemic context. These partnerships began with commitments from senior school district administrators to adopt WISE for inquiry science instruction. These districts have agreed to form a network of teachers supported with paid release time and mentored by a master teacher who is released from regular teaching duties to facilitate the adoption of WISE within the district. We will work closely with administrators from each district to align WISE projects to the relevant state science standards and district curriculum frameworks. Although the districts vary in their technology capacity, each is committed to supporting WISE with Internet connected computers for all participating teachers. These are typical, diverse districts, providing typical supports for the WISE program. Our ongoing research program will investigate the elements necessary for WISE to succeed in these districts.

ENDNOTE

1. These two WISE activities were both developed in partnerships by the SCOPE project, also funded by the National Science Foundation. SCOPE is investigating the role of controversy in science education and is described in detail in Bell (chap. 10, this volume).

Internet Environments for Science Education

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We dedicate this book
to Matthew, Allison, Lucy,
Zoë, and Sophie.