SCAFFOLDING MIDDLE SCHOOL STUDENTS' PROBLEM-SOLVING

IN WEB-ENHANCED LEARNING ENVIRONMENTS

by

MINCHI C. KIM

(Under the Direction of Michael J. Hannafin)

ABSTRACT

The study of technology's role in problem solving has proven both intriguing and elusive. This has been evident in attempts to reconcile the instructional technology field's learning and design traditions with the varied problem-solving perspectives across disciplines and the corresponding classroom practices of teachers. Differences in learning and teaching contexts, beliefs and understandings of problem-solving processes, and approaches to support students during problem solving contribute to the complexity of study. In particular, despite much emphasis on scientific inquiry stressing both content and process knowledge (National Research Council, 1996, 2000), supporting student-centered problem-solving activities in Technology-Enhanced Learning Environments (TELEs) has proven challenging.

The purposes of this qualitative case study were to examine how peers, teachers, and technologies facilitate problem solving in science classes and to identify critical issues and factors associated with problem solving in inquiry-supported TELEs. Data were collected from 19 sixth-grade students and a teacher in two project-oriented, technology-rich classes. Findings indicate that problem-solving patterns and strategies for identifying, exploring, and revising problems varied and that the students benefited from explicit and structured scaffolding to link their prior knowledge, evidence, and multiple perspectives to the problem-context.

Chapter 1, written for an instructional technology audience in a journal-ready format, discusses diverse perspectives on technology-enhanced problem solving, identifies issues associated with problem solving in TELEs, and describes implications for research. Chapter 2, written for science educators in a journal-ready format, proposes a pedagogical framework of inquiry tools in science classes that emphasizes the roles of technologies, teachers, and peers. Chapter 3 summarizes methods and findings from three preliminary studies that guided this study. Chapter 4 is a research paper in a journal-ready format that contains detailed methods, findings, discussion, and implications of the study.

INDEX WORDS: Web-enhanced learning environments (WELEs), technology-enhanced learning environments (TELEs), scaffolding, scientific inquiry, problem-solving, middle school students

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DEDICATION

This dissertation is humbly dedicated to my God, who is the source of my joy, strength, and wisdom and who scaffolds me every moment to teach me His knowledge, guidance, and love.

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CHAPTER 1

SCAFFOLDING PROBLEM-SOLVING IN CLASSROOM-BASED, TECHNOLOGY-ENHANCED LEARNING ENVIRONMENTS (TELES)[1]

[1] Kim, M. C., & Hannafin, M. J. To be submitted to a *journal for Instructional Technology audience*.

Introduction

While improved problem solving has long been a goal in education, researchers and theorists have advanced markedly different conceptions and methods of study regarding this topic. Gagné and Briggs (1974), for example, regarded problem solving as complex combinations of hierarchically-ordered intellectual skills. Recently, constructivist-inspired perspectives have become increasingly prominent. Vygotsky conceived of the zone of proximal development as the gap between "actual developmental level as determined by independent problem solving" and the level of "potential development as determined through problem solving under adult guidance or in collaboration with more able peers" (p. 86, cited in Pea, 2004).

While interest in improving classroom-based, problem-solving skills has been long-standing, progress has been slow. Some researchers (Hannafin & Land, 2000; Papert, 1987) argue that teachers hold traditional, didactic beliefs and use "old tricks" without substantial, sustainable support for student-centered problem solving. Other researchers note that it is particularly challenging for teachers to promote student problem solving due to competing curriculum and assessment pressures and limited time and resources needed to initiate and sustain support (Cuban, Kirkpatrick, & Peck, 2001; Fishman & Krajcik, 2003; Zhao & Frank, 2003).

With the increased availability and capability of varied technologies, classroom-based problem-solving has become an increasingly attainable, yet still elusive, goal. In response to the proliferation of computers and Internet access, standards and benchmarks that guide teaching and learning practices have been proposed linking technological capabilities to improved student problem solving. For instance, in *Technology Foundation Standards for All Students*, the *National Educational Technology Standards (NETS) Project* identified technologies as "problem-solving and decision-making tools." NETS also advocates the preparation of teachers capable of integrating technologies into their classrooms to foster "students' higher order skills and creativity" in *Educational Technology Standards and Performance Indicators for All Teachers.* Consistent with the rationale behind the standards, proponents claim that through everyday use of computers, students can become technologically literate citizens capable of knowing how to think rather than only what to think (Bransford et al., 2000).

Unfortunately, evidence of effective technology-enhanced problem-solving teaching and learning in K-12 schools has been scarce. Perhaps the most pressing issues are limited understanding of how to support students' problem solving in classroom-based, technology-enhanced learning environments and the lack of a coherent framework to guide their design (Hannafin & Kim, 2003; Jonassen, 2000). The purposes of this paper are to introduce perspectives on technology-enhanced problem solving, to identify issues associated with problem solving in TELEs, and to describe implications for research.

Problem Solving with TELEs

Problem-solving Perspectives

Table 1.1 aligns the problem-solving phases proposed by different researchers. Polya (1957), a mathematician who codified problem-solving processes, analyzed conversations between teachers and students in mathematics classrooms. He proposed four problem-solving steps: understanding the problem, devising a plan, carrying out the plan, and looking back. Bransford and Stein (1984) found that individuals become effective and creative problem solvers when they analyze their own strategies and apply alternative approaches to their problems. Extending Polya's approach, their 5-stage problem-solving model includes identifying problems and opportunities, defining goals, exploring possible strategies, anticipating outcomes and acting, and looking back and learning. To varying extents, these stages are integral to contemporary problem-solving models.

Recent problem-solving models emphasize social and environmental factors, as well as roles of language and tools in defining and understanding individuals' problem-solving processes. According to Pea (1993), problem solving is often conceptualized and enacted as a linear process that occurs in and by individuals as a "tool-free" (p. 67) mental process. Instead, he argues that problem solving is an iterative, rather than top-down, distributed activity that is influenced by texts, tools, and people. From a distributed intelligence perspective, problem solving occurs in social contexts within which students use tools and artifacts collaboratively. Thus, problem solving involves collaboratively and iteratively finding and representing the problem, planning a solution, executing the plan, checking the solution, and reflecting to consolidate learning with assistance from peers, experts, and tools. .

Building upon ecological perspectives emphasizing interactive dynamics between learners and environments (Young, Barab, & Garrett, 2000), Young and Barab (1999) proposed five problem-solving steps: (1) anchoring the problem, (2) goal adaptation, (3) constrained search plan, (4) perceptual tuning, and (5) transfer. In each step, problem solving is stimulated through interactions between the individuals' capacities and intentions and environmental dynamics. Students are not merely exposed to problems; rather, they associate the problem contexts with, and interpret problems through, their own experiences and learning goals.

By synthesizing principles and practices across approaches, problem solving in the current context is defined as a deliberate, learner-directed effort to seek solutions to authentic problems. Accordingly, we have distilled the five problem-solving phases shown in Table 1.2: identification, exploration, reconstruction, presentation and communication, and reflection and negotiation. During problem identification, learners find or generate problems and externalize them by writing down ideas or communicating them to others. Teachers and peers help learners to find authentic problems and to generate their own learning goals by asking questions and sharing experiences. Scaffolds help learners to identify learning goals and problems that are meaningful, appropriate, and situated (Applebee & Langer, 1983). In technology-supported learning environments, Web-based tools can provide a meta-context where students can browse information related to problems and find conflicts, dilemmas, or challenges that drive their inquiry.

Exploration of problems involves the utilization of resources to probe problems and plan investigations. While exploring problems, teachers and peers can help students find anomalies and conflicting evidence by posing questions to help them pursue their goals. During this phase, scaffolds typically emphasize questioning and problematizing based on learners' prior perceptions (Reiser, 2004) in order to seek evidence to reconcile conflicts. Metacognitive scaffolds such as structured activities (Applebee & Langer, 1983) and maintenance of learning goals (Hogan & Pressley, 1997), are often provided to help learners remain on-task and to reduce cognitive load.

During reconstruction, learners build potential solutions and explanations, revising them as they find consistent or contradictory evidence. As students reconstruct problems based on their findings and interpretations, teachers and peers can help students identify, select, and frame resources relevant to answer their questions. Scaffolds help students to connect existing knowledge to novel experience, thus modifying their schemata, which are considered fundamental to meaningful learning (Mayer, 1984; Piaget, 1976). In technology-supported learning environments, students often create artifacts to reconstruct problems by proposing tentative theories and solutions and presenting supporting evidence.

Presentation and communication focus on visualizing or verbalizing solutions and explanations, sharing constructive feedback with peers and teachers, and contemplating how to revise proposed solutions. When students present their tentative problem solutions, they warrant their claims and justify their theories with supporting evidence. During this phase, peer-supported and teacher-supported scaffolds are provided to help students challenge their thinking, consider alternative evidence, and evaluate different solutions.

Finally, during reflection and negotiation, learners reflect on the processes and strategies they use and revise their solutions and explanations. During this phase, scaffolds focus on "active diagnosis" (Hogan & Pressley, 1997) to help students detect errors and faulty reasoning and reflect on learning processes and assessment (Kao & Lehman, 1997). As learners identify, explore, and reconstruct problems, present explanations, and reflect on their learning processes, the experience an increase in their expertise, task authenticity, diversity of perspectives, articulation of theories, and degree of participation. In this regard, the problem-solving phases are cyclical rather than linear processes (Pea, 1993).

Scaffolding Classroom-based Problem-solving

According to Wood, Bruner, and Ross (1976), "scaffolding" describes assistance from experts that enables children to achieve what is beyond their ability to accomplish independently. Scaffolding support that is provided initially is gradually decreased as learners become more capable:

> More often than not, it (the intervention of a tutor) involves a kind of "scaffolding" process that enables a child or novice to solve a problem, carry out a task or achieve a

> goal which would be beyond his unassisted efforts. This scaffolding consists essentially of the adult "controlling" those elements of the task that are initially beyond the learner's capacity, thus permitting him to concentrate upon and complete only those elements that are within his range of competence (p. 90).

Likewise in classroom teaching-learning contexts, Davis and Miyake (2004) describe scaffolding as assistance without which a learner cannot attain a goal or engage in an activity. Social constructivists have characterized classroom-based scaffolding as "the social interaction among students and teachers that precedes internalization of the knowledge, skills and dispositions deemed valuable and useful for the learners" (Roehler & Cantlon, 1997, p. 9).

Scaffolding has been examined in studies dealing with interactions between tutor and child (Stone, 1993) and between parent and child in the child's Zone of Proximal Development (ZPD) (Pratt, Green, MacVicar, & Bountrogianni, 1992). Scaffolding has also been studied extensively in classes dealing with reading and writing (Applebee & Langer, 1983; Palincsar, 1986; Pea & Kurland, 1987), science (Hogan & Pressley, 1997), and mathematics (Schoenfeld, 1991). Typically, scaffolding is provided by more capable others to assist learners to achieve what they cannot accomplish independently; typically, scaffolds are gradually faded as the locus of responsibility shifts to learners. Research involving different domains, classroom settings, and student age and ability has generally shown that scaffolding is effective when it is provided through both verbal discourse, teacher modeling, and pedagogical tool-based strategies such as triggering student sense-making (Quintanna et al. 2004), problematizing tasks (Reiser, 2004), and visualization and representations of knowledge (Linn, Clark, & Slotta, 2003).

Scaffolding Technology-enhanced, Classroom-based Problem-solving

Recent attention has focused on providing technology-enhanced scaffolds to provide conceptual and metacognitive assistance [see, for example, *The Journal of the Learning Sciences,* 2004, 13(3)]. As shown in Table 1.3, scaffolding helps students to both articulate and act upon problem-solving processes and learning activities. According to Reiser (2004), scaffolding via computer tools can assist students in structuring complex tasks by "problematizing" (p. 282) content knowledge. For example, concept maps and semantic networks (e.g., STELLA) have long been used to organize and articulate thinking. Recently, researchers have used electronic portfolios to trace students' and teachers' learning processes and to share exemplary practices. Land and Zembal-Saul (2003), for example, found that computer-based scaffolding designed to promote reflection and articulation in physics (Progress Portfolio) helped pre-service teachers to frame and revise questions and explanations.

TELEs can help to situate problem identification in students' daily experiences by providing vivid descriptions, visualizations, and related questions and resources. For example, the *Web-enhanced Inquiry Science Environment (WISE)*[2] engages students in provocative science dilemmas to inspire students to formulate explanations based on evidence. Another environment, *Science Controversies On-line: Partnerships in Education [SCOPE]*[3], provides an electronic space where students explore what scientists do, how they investigate problems in the real world, and how controversy (e.g., global warming) is debated in scientific communities.

Consistent with Salomon, Perkins, and Globerson's (1991) conception of intellectual partnerships, technologies can facilitate exploration by supplanting lower-order tasks such as

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[2] Available at http://wise.berkeley.edu/
[3] Available at http://scope.educ.washington.edu/

simple calculations and typing, thereby allowing students to allocate cognitive resources to higher-order tasks such as generating hypotheses, seeking and identifying variables, and examining alternatives. Computer-based modeling tools can support problem solving by supplying simulations, visualizations, and 3D models [see, for example, the Virtual Solar System (Barab, Hay, Barnett, & Keating, 2000) and Model-It (Jackson, Krajcik, & Soloway, 2000)].

TELEs have also scaffolded student diagnosis and reconstruction of misconceptions [e.g., "advisors" in SCI-WISE (White, Shimoda, & Frederiksen, 1999) and text-based questions in Progress Portfolio (Edelson, 2001)]. For instance, students receive procedural assistance to do inquiry and self-assessment using STAR.LEGACY, through which they address challenges, generate ideas, consider multiple perspectives, conduct research, revise hypotheses, and communicate their findings (Schwartz, Lin, Brophy, & Bransford, 1999). Stories can also provide a powerful bridge between student experience and the learning context (Jonassen, 2003). Video-based vignettes in the Jasper Series, for example, helped students to identify sub-problems, variables, and other relevant information, and to utilize it to inform their decisions (e.g., the best ways to rescue an eagle, CTGV, 1992). By playing and replaying stories, students accommodate and adapt the problems to their own practices.

During *presentation and communication*, teachers and peers guide students' in justifying their ideas via collaboration. According to Koschmann et al. (1994), the principle of multiplicity indicates that instruction should reflect the nature of knowledge as "complex, dynamic, context sensitive, and interactively related" (p. 233) by introducing diverse views and resources. Technology can foster ready access to diverse perspectives on human activities, natural phenomena, and societies, supporting collaborative knowledge construction (e.g., Knowledge

Forum[4], Computer-Supported Intentional Learning Environments [CSILE], Scardamalia & Bereiter, 1992), case-based learning (e.g., Knowledge Innovation for Technology in Education [KITE][5], Wang, Moore, Wedman, & Shyu, 2003), multiple knowledge representations (e.g., WorldWatcher[6], GLOBE[7], Edelson, 2001), and multiple perspectives and interpretations (e.g., MediaMOO[8]).

Finally, teachers and peers can scaffold *reflection and negotiation* in TELEs by guiding students to reflect on their problem-solving processes and assess their progress. The Jasper project scaffolds these activities via situated, authentic problems, providing opportunities to transfer learning outcomes to novel problems and broader contexts. By solving these problems, students develop episodic knowledge that can be applied in daily experience (Nespor, 1987). Web-based, distributed knowledge communities such as CSILE, SCOPE, MediaMoo, and NewsMaker (Evard, 1996) may empower students to communicate and negotiate with peers, teachers, and experts.

Issues in Scaffolding Classroom-based, Technology-enhanced Problem-solving

Several challenges stem from the complexity associated with problem solving and often demand considerable cognitive resources. Other challenges, however, emerge from efforts to implement technology-enhanced problem solving in everyday teaching and learning settings. In this section, we review and analyze the difficulties associated with peer-, teacher-, and technology-enhanced problem solving in K-12 classrooms.

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4 Available at http://www.knowledgeforum.com/
5 Available at http://kite.missouri.edu/
6 Available at http://www.worldwatcher.northwestern.edu/
7 Available at http://www.globe.gov/
8 Available at http://www.cc.gatech.edu/~asb/MediaMOO/

Peer Scaffolding

Cognitive overload is perhaps the most often cited challenge faced by students (Hannafin, Hill, Oliver, Glazer, & Sharma, 2003). Technology-based tools often require considerable cognitive capacity to skim, grasp, and manipulate a wide range of data. Students can become disoriented in Web-based learning environments due to the large number of resources encountered and their limited readiness. Pederson and Liu (2003) report "floundering" during student-centered learning activities in a computer-based science program, *Alien Rescue*. Oliver and Hannafin (2000) note that 12 middle school students, when asked to frame and resolve earthquake engineering problems with *Knowledge Integration Environments* (KIE), used procedural scaffolding extensively to complete tasks, but little conceptual support to explore "how or why" questions related to phenomena under study. Likewise, Land and Hannafin (2000) caution against "learner compliance" technology-enhanced learning. In their study, students tended to search for answers that satisfied teachers' expectations rather than attempting difficult problems, posing dilemmas, or exploring alternative explanations.

Students are inherently limited in their ability to think critically or solve complex problems when they lack adequate prior knowledge and experience (Land & Hannafin, 2000). Among students with limited background knowledge, embedded scaffolds are of limited use for developing understanding compared with students with adequate background knowledge (Land & Zembal-Saul, 2003). Furthermore, when they fail to recognize contradictions, students tend to accommodate novel learning experiences within their existing, naïve theories. In effect, attempts to challenge student understanding using contradictory evidence may go undetected, unwittingly reifying rather than challenging existing conceptions.

Several attempts to facilitate student accommodation to and adaptation of technologies have been advanced. In an effort to overcome student misconceptions and the lack of authentic science experience, Linn and her colleagues developed the Scaffolded Knowledge Integration Framework (Linn, 2000; Linn & Hsi, 2000). Multiple principles are employed to support students as they engage in technology-enhanced science projects: making science visible, making thinking visible, helping students learn from each other, and promoting lifelong science learning (Linn, Clark, & Slotta, 2003). Linn and Davis (2000) report that KIE (Knowledge Integration Environment) prompts, based upon these design principles, helped students to used to reflection on and monitor their inquiry processes.

A final issue, grounded in sociocultural perspectives and situated cognition theory, is related to the role of collaboration. Considerable research has been conducted in computer-mediated communication (Holden & Wedman, 1993), distributed problem-based learning (Koschmann, 2002), computer-supported collaborative learning (Koschmann, Kelson, Feltovich, & Barrows, 1996), and online communities (Hill, 2002; Rovai, 2001). Researchers have identified a myriad of collaborative learning issues, such as difficulties in sharing a common vision among collaborators (Hannafin, Hill, Oliver, Glazer, & Sharma, 2003), scaffolding peer collaboration (Ge & Land, 2003), and establishing meaningful problem-solving goals (Barron, 2000). Krajcik et al. (1998) note that peer collaboration problems arise, to some extent, from students' inabilities to systematically link evidence to plausible arguments and monitor group work.

Disciplined study can provide important insights related to individual and collaborative problem solving; unfortunately, research has rarely influenced classroom practices. In practice, multiple forms of scaffolding interact within everyday classroom contexts, establishing authentic conditions different from controlled settings where studies have been implemented. Approaches are needed that account for the interactions between and among peers, teachers, and technology.

Teacher Scaffolding

Research has been criticized for being anecdotal; lacking a compelling, unifying theoretical framework (Windschitl & Sahl, 2002); providing little direct evidence of putting teaching principles into actual practice; and disregarding interdependence among factors associated technology use (Zhao & Frank, 2003). Professional domain knowledge and experience are important because teachers model authentic inquiry processes and co-construct knowledge (Crawford, 2000; Keys & Bryan, 2001). Nespor (1987) suggests that episodic knowledge, grounded in teachers' own experiences, provides insights into how learning experiences and critical incidents can be shared. Land and Zembal-Saul (2003) used Progress Portfolio, a computer program designed to scaffold scientific reflection and articulation during pre-service teachers' project-based learning. Their study reveals that computer-based scaffolds were not used constructively when "teachers failed to detect when learners were not generating appropriate explanations" (p. 80).

Epistemic beliefs pose another potential barrier to implementing student-centered TELEs. Cuban (2001) reports that even teachers who used computers in their everyday planning and teaching held traditional teaching and learning beliefs. Few transformed the way they taught: "When we shadowed teachers and students, however, we saw what classroom researchers have seen for decades" (p. 95). While influenced by a lack of time, limited resources, and teaching pressure, teachers reported preferences for technologies that ”fit" existing, didactic instruction; many were unaware of how to promote student-centered learning using technology.

While some suggest that factors such as teacher age and computer experience do not impact technology implementation (Cuban, Kirkpatrick, & Peck, 2001), others suggest that teachers' attitudes toward and experience with technologies are crucial (Becker, 1998; Zhao & Frank, 2003). In some cases, negative attitudes arise from encounters with unreliable technologies (Cuban, 2001) and defective technologies (Cuban et al., 2001). That is, many teachers are not inherently disposed against technology use, but become increasingly skeptical as they unsuccessfully attempt to use technology.

Finally, teachers suggest that many day-to-day constraints to scaffolding, such as limited planning time, lack of shared resources (Barab, MaKinster, Moore, & Cunningham, 2001), and a mismatch between learning goals and teaching practices, are systemic in K-12 contexts. Pederson and Liu (2003) describe conflicts between the goal of promoting student-centered learning and preparing students for standardized tests among teachers implementing *Alien Rescue*.

Research has rarely reflected critical aspects of individual teacher-student interactions or reflected realistic applications of technology in everyday classroom contexts. As with peer scaffolding, we need to better understand teachers' contributions to, and interplay among, students, peers, and technology in realistic classroom settings.

Technology-enhanced Scaffolding

Although tools and guidelines have been created to support learning and teaching, critics suggest that they emphasize intuitive beliefs that fail to either reflect how students learn or optimize technological affordances (Hannafin, Kim, & Kim, 2004). In practice, students often experience difficulty generating questions in open-ended problem environments without assistance (Oliver & Hannafin, 2001; Sharma, 2001). In contrast, students who use scaffolds in the form of resources or tools tend to be successful in finding or generating problems (Danielson, Bender, Mills, Vermeer, & Lockee, 2003). Technology-enhanced scaffolding, such as *WISE's Ocean Stewards* problem identification support for helping students to select locations for further investigation from among given online marine sanctuaries (Linn, Clark, & Slotta, 2003), can help students to identify authentic, situated problems during initial problem-solving stages.

The manner in which guidance is worded, chosen, and presented via TELEs can also influence scaffolding use and effectiveness (Rivet & Krajcik, 2004). Critics suggest that direct approaches, such as telling students which problems to solve or how to solve them, may undermine rather than cultivate problem identification. Learners may become cognitively compliant and simply "obey" directions rather than internalize guidance (Hannafin & Land, 2000). Indeed, researchers have found that rather than internalize problem-solving guidance, students depended on prompts and supports and were unable to enact problem-solving strategies independently once the supports were removed (Oliver & Hannafin, 2000).

Several factors appear to influence the effectiveness of TELE scaffolding. First, problems need to be consistent with the epistemology embodied in the learning environment (Hannafin, Hannafin, Land, & Oliver, 1997). The nature and specificity of scaffolds influence their effectiveness. Metacognitive scaffolding may be especially important for students who lack prior domain knowledge, as they guide in identifying naïve assumptions and resolving problems (Merenluoto & Lehtinen, 2004; Palmer, 2003). However, little is known about how much (or where) scaffolding should be embedded. *WebQuests* provide scaffolds to structure lesson designs using teacher-prescribed problems and teacher-supplied steps and resources. In contrast, the *Jasper Series* (CTGV, 1992, 1997) utilizes an exploratory approach that does not specify explicit problem-solving paths or strategies. In some cases, tailored, technology-based assistance, such as inquiry maps, hints (see, for example, WISE, Linn, Clark, & Slotta, 2003), or simulations (see, for example, WorldWatcher, Edelson, Gorden, & Pea, 1999) may provide support available via neither peers nor teachers. In classroom applications, technology-enhanced scaffolding needs to complement the support provided by peers and teachers.

Classroom Implementation

The difficulties involved in researching classroom-based innovations are not new; problems associated with introducing technological innovations into everyday classrooms have long-standing and deeply-rooted epistemological and cultural roots. For example, LOGO's mixed success in improving students' understanding was attributed to a mismatch between the innovation's student-centered epistemology and the prevailing teacher-centered classroom culture (Papert, 1987). Similarly, during early efforts to develop the *Jasper Series*, teachers often appropriated the problem-based mathematics resources to more traditional teaching-learning approaches (Barron, Bransford, Campbell, Ferron, Goin, Goldman et al., 1992). Cuban et al. (2001) describes the "paradox" of schools with high technology access but low use—only 13 out of 21 teachers indicated they had changed their practices through the use of technology. Cuban attributed slow evolution to school culture, historical legacy of schools as being "academic" institutions, structure and time constraints, and defects in technology that led to "ad hoc incrementalism" (p. 830).

Still, several researchers have successfully implemented classroom-based, technology-enhanced problem-solving innovations. For example, the University of Michigan's Hi-CE (the Center for Highly Interactive Computing in Education) research focuses on technology-supported, project-based learning in urban curricula (Blumenfeld, Fishman, Krajcik, Marx, & Soloway, 2000). The *WISE* research group collaborates with teachers in California, as well as those elsewhere in the United States and world (Linn & Hsi, 2000). Vanderbilt's SMART project group integrated *Jasper* into the curricula of several schools and school districts nationwide (CTGV, 1997). We need to examine contextual factors that facilitate or hinder TELE-based problem solving.

TELE Scaffolding in Context: An Example from Science Education

Scientific Inquiry as Situated Problem-solving

Historically, inquiry has been enacted in teaching and learning through questioning and answering. Inquiry has been defined as an examination into facts or principles, a request for information, and a systematic investigation often of a matter of public interest (Merriam-Webster, 2003). Traditional classroom inquiry strategies are largely consistent with this definition.

Recently, however new definitions and practices have emerged—especially in science education. According to the National Research Council (1996), inquiry involves the processes of observing phenomena, generating questions, investigating resources, utilizing tools, generating explanations, and sharing answers. The *National Science Education Standards* (NSES) identify three aspects as critical to inquiry learning: (1) identification of assumptions; (2) use of critical and logical thinking; and (3) consideration of alternative explanations (p. 23). Scientific inquiry mirrors the various ways that scientists examine the natural world by generating interpretations from evidence. As students engage in scientific inquiry, they come to know scientific ways of studying the natural world. To attain this goal, the NSES suggests five learner-centered factors in inquiry learning and teaching: (1) learners are engaged by scientifically oriented questions; (2) learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions; (3) learners formulate explanations from evidence to address scientifically oriented questions; (4) learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding; and (5) learners communicate and justify their proposed explanations.

Figure 1.1 illustrates how problem solving can be scaffolded during Web-enhanced, classroom-based scientific inquiry. Students find authentic questions that reflect natural phenomena in the world *and* that can be examined through classroom activities, explain answers to the questions based on the evidence they find from the natural world, and justify their explanations by sharing the results with peers. Students explore problems and questions related to their daily experiences, and the findings from their explorations reflect the solutions to everyday inquiries and problems (Kim & Hannafin, 2004).

A Framework: Inquiry-supported Problem Solving with TELEs

Figure 1.2 associates scaffolding with problem-solving phases and inquiry activities. The framework supports the inquiry activities specified in the National Science Educational Standards (NRC, 1996), suggests technology roles for those activities, and indicates how scaffolding (peer-, teacher-, and technology-enhanced) supports each problem-solving phase.

In the framework, problem identification embodies student activities such as making observations of natural phenomena through utilizing visualizations and reading in TELEs. During identification, students find or generate interesting problems that they plan to investigate further. In some TELEs, students can select a meaningful problem or project from among alternatives (see, for example, the *Ocean Stewards* project in *WISE*, Linn, Clark, & Slotta, 2003). Hands-on-activities can be embedded to help students find authentic problems and engage tasks [see, for example, the *Create-a-World Project* in *WorldWatcher* (Edelson, 2001)].

In inquiry-supported TELEs, problem exploration involves examining multiple resources, planning investigations, and utilizing tools. In the *Kids as Global Scientists* project[9], for example, students assume the role of local weather experts to solve climate problems by accessing pre-selected Web-based resources (Mistler-Jackson & Songer, 2000). In order to forecast local weather at the end of the project, students access real-time resources and data as they address and solve problems related to clouds, humidity, winds, precipitation, temperature, and pressure.

The problem reconstruction phase incorporates student activities for proposing answers, explanations, and predictions about the problems explored. For instance, *SCI-WISE ThinkerTools'* meta-context scaffolds students' scientific investigations: *Question, Hypothesize, Investigate, Analyze, Model, and Evaluate*. To design and do experiments, and to collect data to test hypotheses, students reference models embedded in *ThinkerTools*. Next, students analyze data to find salient patterns, generate models based on their analysis, and apply those models to novel problems to evaluate their models. During each inquiry cycle, problem solving is scaffolded by embedded *SCI-WISE* technology-based advisors, as well as by peers and teachers providing procedural and strategic scaffolds such as how to question, hypothesize, investigate, plan, reason, and represent (White, Shimoda, & Frederiksen, 1999).

Problem presentation and communication are typically integral to collaborative inquiry activities such as sharing ideas and communicating results. Inquiry tools support peer collaboration using bulletin boards and chat rooms, as well as student-expert collaboration. In *SCOPE—Controversy in Space*, introductory descriptions prompt students to do inquiry as scientists and to communicate with scientists (see Figure 1.3). Students engage an inquiry

[9] Available at http://www.onesky.umich.edu/kgs01.html

question that guides investigation (e.g., discussions about scientific controversy), review resources proposing competing conclusions and finding further evidence, and present informed positions on the controversy. Students develop Notes, Journals, and other artifacts (such as PowerPoint Slides to develop a grant proposal) and share feedback with peers, teachers, and scientists.

Finally, problem reflection and negotiation involves reflective learning activities such as justifying, defending, and revising ideas and solutions. As shown in Figure 1.4, WISE prompts students to record their notes electronically, but scaffolds the request to clarify appropriate documentation (e.g., describing new evidence, providing support for validity of evidence, documenting Web addresses). WISE also provides hints for references to further scaffold reflection (e.g., “Do you know the source and author of the evidence?”, “Is the site current and does the science seem valid?”, “Does the author use evidence to support the claims he/she makes?”). Students can also use discussion boards and chat rooms to post solutions and receive feedback from peers and teachers.

Implications for Research

Can Scaffolding Help Students to Solve Inquiry Problems Where They Lack Background Knowledge?

Research has consistently shown that when students lack prior domain-specific knowledge, they are often unable to solve well-structured problems (Shin, Jonassen, & McGee, 2003). This issue is critical in problem-solving environments, which rely heavily on students’ ownership over their learning. Where learners lack adequate prior knowledge, naïve assumptions and theories may limit or fail to adequately inform their inquiry processes. As a result, they tend to develop robust and oversimplified misconceptions that prove highly resilient to change. This "situated knowledge paradox" (Hannafin & Land, 2000, p. 14) is especially problematic in inquiry-based problem solving because students initiate activities by finding or generating authentic, driving questions based heavily on their own knowledge and experience.

Although inquiry has been studied for decades and numerous tools have been developed since the National Science Education Standards (NRC, 1996) were proposed, we know surprisingly little about how (or if) these tools influence student conceptions through TELE-scaffolded inquiry processes. For instance, we need to identify the challenges students face during problem-solving and inquiry activities, as well as the strategies they utilize to overcome them. Additionally, we need to document when peer-, teacher-, and technology-enhanced scaffolding designed to challenge students' naïve assumptions are (and are not) effective. Finally, the influence of and interactions among scaffolding activities designed to mitigate limited prior knowledge and experience requires further study to assess their interdependency.

What Do Students Learn through Collaborative Problem-based Inquiry?

Research on the influence of group or collaborative learning has proven promising; indeed, collaboration is employed in many TELEs (Coleman, 1998; Krajcik, Blumenfeld, Marx, Bass, Fredricks, & Soloway, 1998). According to Schwartz (1995), for example, student dyads are generally better able to apply problem-solving strategies than are students working individually. Researchers have also found that collaboration improved performance in short-term problem-solving projects (Barron, 2000; Stevens & Slavin, 1995; Webb & Palinscar, 1996).

However, group performances may obscure what is actually learned and understood by individuals within groups; individuals may perform worse, not better, in groups (Barron, 2003). These differences may be a function of the interplay between individual differences and various social and cognitive factors involved in collaborative problem solving. For instance, individual prior knowledge, experience, motivation, learning patterns, argumentation skills, and openness to alternatives may be masked during grouping and group interaction due to the social nature of negotiation and meaning-making (Barron, 2003; Coleman, 1998; Schwartz, 1995).

This dilemma is especially problematic during inquiry-supported problem solving. Although the National Science Education Standards define scientific inquiry as “the diverse ways in which scientists study the natural world” (NRC, 1996, p. 23) and characterize “communicating the results” as an essential inquiry activity, the standards fail to address how communities of scientists do (and do not) collaborate and communicate. Barron (2003) suggests that the “quality of interaction” (p. 307), such as willingness to discuss both correct and flawed solutions, influences group success more than prior achievement or the accuracy of initial solutions proposed. Oliver and Hannafin (2001) found that general ability composition influences the quality of solutions to inquiry problems, with heterogeneous ability students generating more original and meaningful solutions to inquiry problems than homogeneous high- or low-ability students.

Research is also needed to investigate how students, as novices, model scientists’ practices and strive to engage in an expert’s community. We need to identify and understand student interactions during collaborative inquiry processes and to examine strategies that foster effective peer-peer, peer-teacher, peer-scientist, and peer-technology interactions.

Do Teachers Implement Technology-enhanced, Problem-based Inquiry in Their Classrooms?

Traditionally, problem-solving research has centered on student learning; researchers often attribute failure to a lack of understanding of deficient problem-solving skills (Jonassen, 2000). Recently, with the growing interest in technology in K-12 learning environments, attention has shifted to the teachers’ roles (Kim, Hannafin, & Bryan, 2004; Kim, Hannafin, &

Bryan, in preparation). Several tools have been developed to assist teachers to incorporate technologies into their classrooms (e.g., Inquiry Learning Forum, Barab, MaKinster, Moore, & Cunningham, 2001; case-based libraries, Kim, Hannafin, & Kim, 2004).

In science education, the focus on inquiry learning has highlighted several problems: a shortage of models, lack of guidelines for teachers, and difficulty in transferring lessons learned from one inquiry setting to another context (Shiland, 1998, 2002). Some researchers have reinforced the importance of, and requirements for, teacher preparation to implement complex student-oriented, open-ended inquiry processes (Bryan & Atwater, 2002). Crawford (2000), for example, conducted an in-depth analysis of the practices of a successful high school biology teacher who continuously devised and implemented meaningful inquiry activities for his students. She concluded that teachers play multiple roles in inquiry classes, including situating instruction in authentic problems, grappling with data, collaborating with students and teachers, connecting students with the community, modeling the behaviors of a scientist, and fostering student ownership. In technology-enhanced inquiry classes, teachers' roles become even more crucial. Kim, Hannafin, Adams, and Bryan (2004) suggest additional roles of teachers in TELEs, as designers, problem solvers, context analysts, coaches, and evaluators. The skills needed to implement TELE-enhanced, problem-based inquiry may prove to be substantially different from those emphasized in traditional pre-service and in-service education.

It is important to study alternatives to preparing pre- and in-service teachers for technology-enhanced inquiry classes. Several questions need to be examined: What influences teachers to change their teaching and learning beliefs to implement student-oriented problem-solving learning environments? How do personal and professional experiences guide teaching practices in technology-enhanced inquiry classes? How can pre-service and professional development programs support teachers in linking new knowledge with their existing teaching practices in everyday classroom settings?

Which Approaches to Scaffolding Problem-solving in TELEs Are Effective?

Many researchers have advocated the use of open-ended learning tasks as an alternative to didactic teaching practices. However, students require support to enact the problem-solving processes associated with full inquiry and partial inquiry (NRC, 2000). Teachers may provide direct answers to open questions in their classrooms because their experience and beliefs reinforce such practices; indeed, some researchers report that didactic instruction can help students who lack prior domain knowledge to engage in problem-solving tasks (Schwartz & Bransford, 1998).

Little is known about how to scaffold higher-order problem-solving processes and how to model those processes for the student. Video-based teaching examples provide teachers with concrete, contextualized teaching vignettes (Simmons, Emory, Cater, Coker, Finnegan, & Crockette et al, 1999); evidence of their impact, however, remains rare. Such research may yield important insights needed to both analyze and scaffold key problem-solving and inquiry practices. Research is needed to determine which scaffolding activities facilitate inquiry.

How Should Technology-based Scaffolding for Inquiry Be Designed and Implemented?

While there is no dearth of problem-solving tools or tips, little is known about how to deploy multiple scaffolds; moreover, little research has been conducted related to the interaction among the scaffolding alternatives presented in the framework (teacher, peer, and technology). Traditional scaffolding research, for example, focused on verbal cues and question prompts; TELE research has centered on embedded scaffolding of technology-based inquiry tools (Davis & Miyake, 2004).

Pea (2004) argues that "scaffolds are not found in software but are functions of processes that relate people to performances in activity systems over time" (p. 446). Reiser (2004) suggests that scaffolding be examined as a system:

> A final caution to be discussed in exploring models of scaffolding in software tools is that learners, tools, and teachers work together as a system, and it is an oversimplification to consider how tools can scaffold learners without considering the other aspects of this system (p. 298).

In classroom practice, scaffolding encompasses the teacher, peers, and technology. Problem solving requires learners to plan and execute inquiry activities; these activities need to be scaffolded in complementary ways. Several questions warrant investigation: What are the relationships among different types of scaffolding? When technology-enhanced scaffolding is provided, can teacher scaffolding be faded? If learners become dependent on technology-enhanced scaffolding, do they interact less with peers or teachers? When students identify, explore, reconstruct, present, and reflect on inquiry problems, do they utilize the different scaffoldings in different ways?

Conclusion

The scaffolding of problem solving requires consideration of many factors. Scaffolding is neither trivial to design nor easy to implement. However, technology-enhanced scaffolding has demonstrated potential to assist student problem solving beyond what peer or teacher scaffolding alone provides. Despite the ubiquitous access to computers and technologies and the promise of new, improved technologies, our ability apply this potential to problem solving has proven disappointing. Our linking of problem solving, inquiry and technology in classroom settings provides a much-needed framework to guide future research, theory, and practice.

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TABLES AND FIGURES

Table 1.1. Phases and learning activities across problem-solving models

Problem-solving phases	Learning activities	Polya (1957)	Bransford & Stein (1984)	Pea (1993)	Young & Barab (1999)
Identification	• Generate or find problems • Externalize defined goals and problems	• Understand the problem	• Identify problems and opportunities • Define goals	• Find the problem • Represent the problem	• Anchor problem • Goal adoption
Exploration	• Use resources to probe into the problems • Plan the investigation processes	• Devise a plan	• Explore possible strategies	• Plan a problem solution	• Constrained search plan
Reconstruction	• Build potential solutions and explanations • Revise them as conflicting evidences are found	• Carry out the plan	• Anticipate outcomes and act	• Execute the plan • Check the solution	• Perceptual tuning
Presentation/ Communication	• Visualize and/or verbalize the solutions and explanations • Share constructive feedback	• Look back	• Look back and learn	• Reflect to consolidate learning	• Transfer
Reflection/ Negotiation	• Reflect on the processes and strategies used to solve the problems • Revise the solutions and explanation				

Table 1.2. Teacher-enhanced and peer scaffolding in each problem-solving phase

Problem-solving phases	Salient characteristics of scaffolding	Scaffolding goal(s)	Sample questions asked during peer- and teacher-enhanced scaffolding
Identification ↕	• Intentionality • Appropriateness of task/problems (Applebee & Langer, 1983) • Pre-engagement • Establishment of a shared goal (Hogan & Pressley, 1997) • Situation definition • Intersubjectivity (Wertsch, 1984)	• Help students find/generate authentic problems • Help students identify/clarify individual interests • Help students find/generate their own goals in this problem solving	• “Is this problem something you are really interested in? Why?” • “Have you thought about this kind of problem before?” • “Is this a problem that you are able to explore and find solutions? Why?”
Exploration ↕	• Structure (Applebee & Langer, 1983) • Questioning & problematizing (Reiser, 2004) • Maintenance of learning goals (Hogan & Pressley, 1997)	• Provide resources for students to explore for evidence • Help students identify anomalies and conflicting evidence • Help students to continue to pursue solutions	• “What kind of evidence are you looking for?” • “Do you think this information would be useful for finding answers?” • “What kind of difficulties did you find while playing with the problem?”
Reconstruction ↕	• Internalization (Applebee & Langer, 1983) • “Tailored” assistance (Hogan & Pressley, 1997) • Assistance of internalization, independence, and generalization to other contexts (Hogan & Pressley, 1997)	• Help students select and frame resources relevant to answer their questions • Help students connect their evidence to theories • Help students correct naïve assumptions	• “Tell me about theories and solutions that you came up with.” • “How did you link the resources you found to the theories?” • “How did you correct the old theory/assumptions?”
Presentation/ Communication ↕	• Collaboration (Applebee & Langer, 1983) • Feedback (Hogan & Pressley, 1997) • Control of frustration and risk (Hogan & Pressley, 1997) • Semiotic mediation (Wertsch, 1984)	• Help students collaborate with peers and share constructive comments • Help students present and justify their ideas and theories	• “How’s your collaboration going?” • “What useful feedback did you get?” • “Did you learn anything interesting from other students’ work?” • “What would you say to those who think your theory is wrong because…?”
Reflection/ Negotiation	• Active diagnosis (Hogan & Pressley, 1997) • Engagement in ongoing assessment (Kao & Lehman, 1997)	• Help students reflect on their problem-solving processes • Help students continually assess their learning processes	• “What did you learn from this class?” • “What would you have done differently?”

Table 1.3. Technology-enhanced scaffolding in each problem-solving phase

Problem-solving phases	Salient characteristics	Technology-enhanced scaffolding	Representative TELE features
Identification ↕	• Intentionality • Appropriateness of task/problems (Applebee & Langer, 1983) • Pre-engagement • Establishment of a shared goal (Hogan & Pressley, 1997) • Situation definition • Intersubjectivity (Wertsch, 1984)	• Providing authentic, situated contexts • Providing vivid descriptions and visualizations	• Capturing stimulating issues in science topics in WISE (e.g., Mystery of Deformed Frogs) • Presenting controversial issues in SCOPE (e.g., declining amphibians)
Exploration ↕	• Structure (Applebee & Langer, 1983) • Questioning & problematizing (Reiser, 2004) • Maintenance of learning goals (Hogan & Pressley, 1997)	• Taking over lower-order tasks • Providing adequate resources	• Calculation and typing features • Simulations, visualizations, and 3D models (e.g., Virtual Solar System, Model-It) • "Filtered" resources from the WWW
Reconstruction ↕	• Internalization (Applebee & Langer, 1983) • "Tailored" assistance (Hogan & Pressley, 1997) • Assistance of internalization, independence, and generalization to other contexts (Hogan & Pressley, 1997)	• Helping students diagnose their misconceptions • Providing procedural assistance to organize learning processes and resources	• Different types of "advisors" in SCI-WISE • Text-based questions in Progress Portfolio • Classified "Activities" in WISE
Presentation/ Communication ↕	• Collaboration (Applebee & Langer, 1983) • Feedback (Hogan & Pressley, 1997) • Control of frustration and risk (Hogan & Pressley, 1997) • Semiotic mediation (Wertsch, 1984)	• Providing multiple perspectives • Providing communication tools	• Knowledge Forum, CSILE • Bulletin board, chat rooms
Reflection/ Negotiation	• Active diagnosis (Hogan & Pressley, 1997) • Engagement in ongoing assessment (Kao & Lehman, 1997)	• Promoting lifelong learning • Providing metacognitive assistance	• Online knowledge communities (CSILE, SCOPE, MediaMOO) • Online Journals and Notes (WISE)

Figure 1.1. Scientific Inquiry (Kim & Hannafin, 2004)

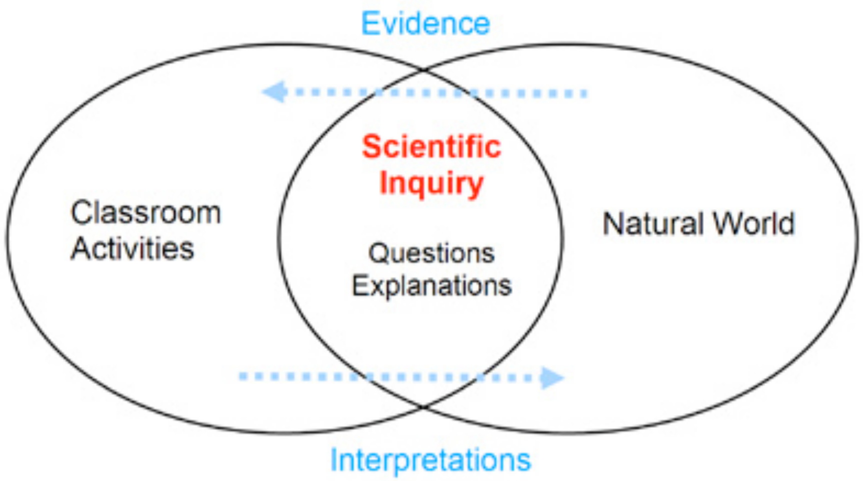


Figure 1.2. Conceptual Framework—Inquiry-supported problem solving with TELEs

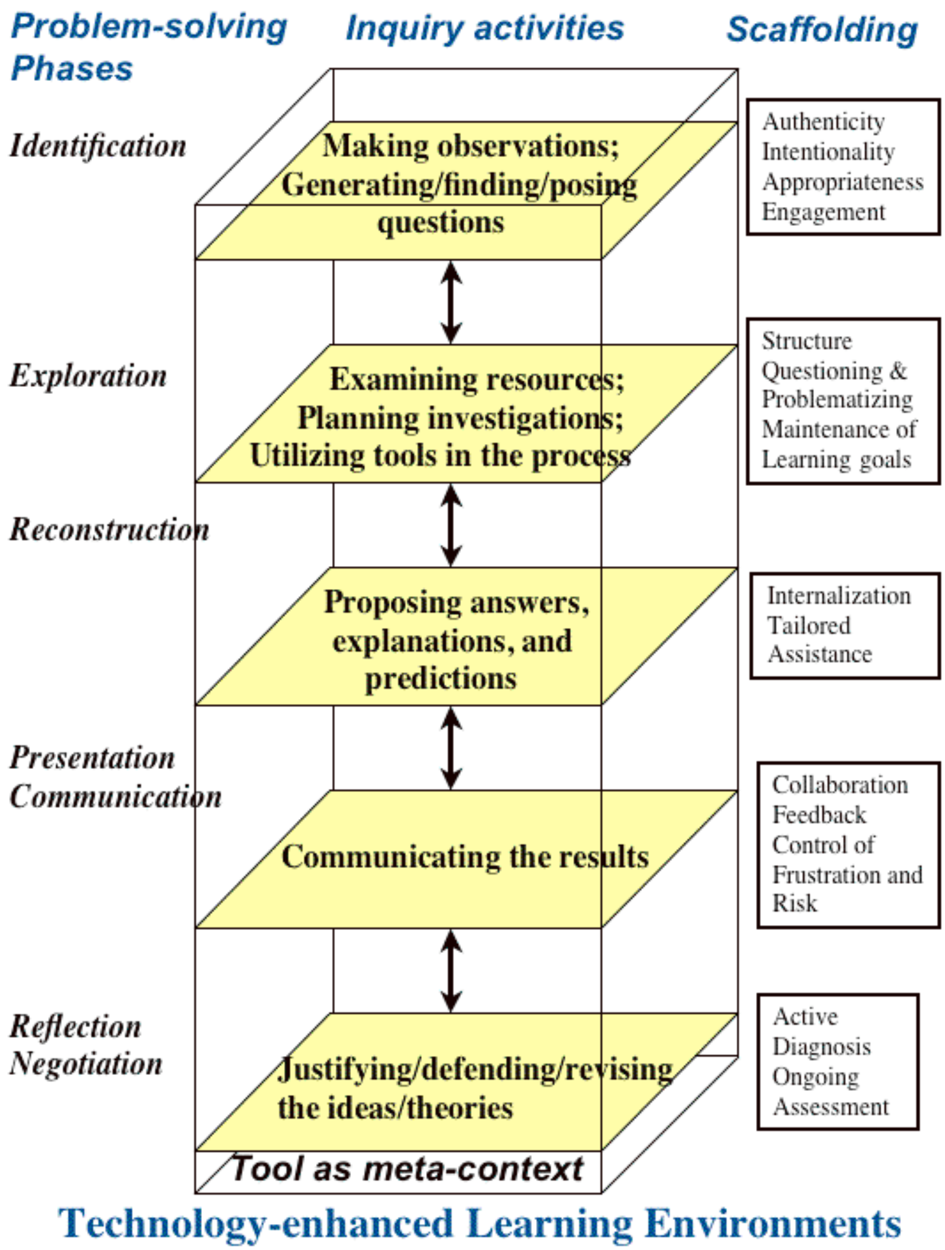


Figure 1.3. SCOPE-Controversy in Space

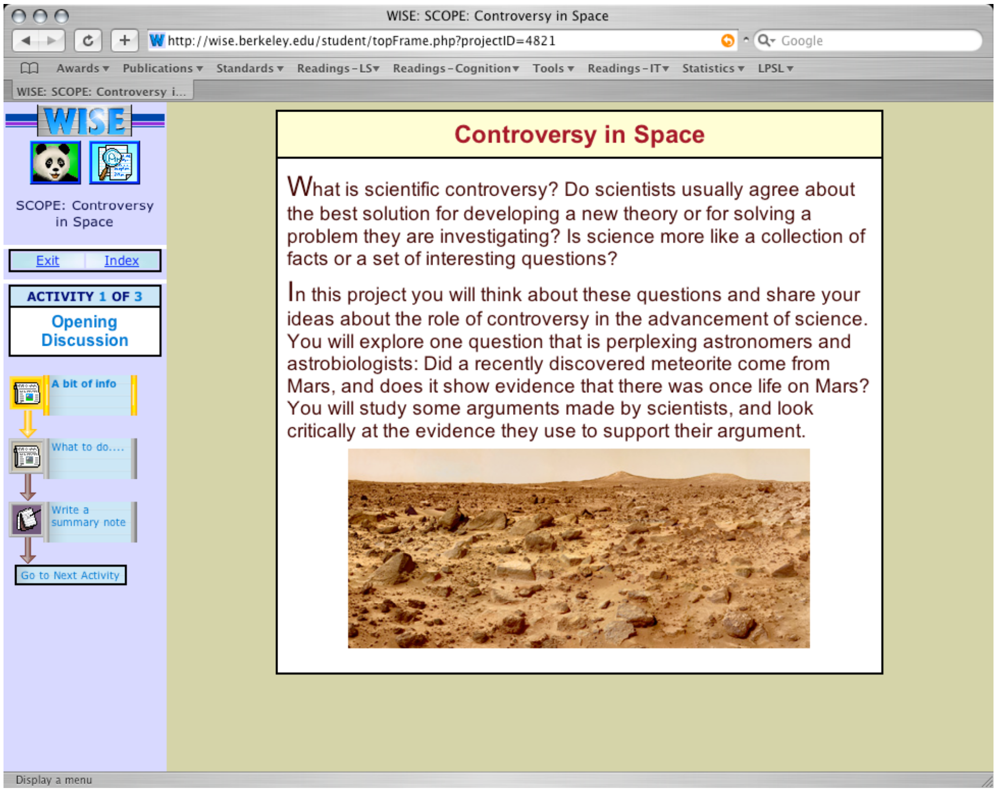
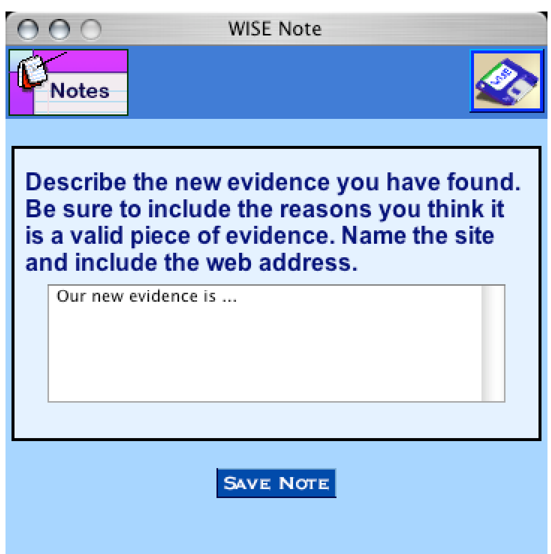


Figure 1.4: WISE—Notes



CHAPTER 2

TECHNOLOGY-ENHANCED INQUIRY TOOLS IN SCIENCE EDUCATION: AN EMERGING PEDAGOGICAL FRAMEWORK[1]

[1] Kim, M. C., Hannafin, M. J., & Bryan, L.A. To be submitted to a *journal for Science Education audience*.

The Challenges

Amy is known as one of the most innovative and enthusiastic science teachers in a suburban middle school in the Southeastern area of the United States. She tries to help students develop their thinking and use technologies meaningfully. In her project-based class, 6th graders work in dyads and triads on interdisciplinary "research" projects across a variety of topics. To encourage her students to experience what scientists do in the real world and to use technologies authentically during their learning processes, she chose a well-known, research-based, Web-based inquiry tool. A great deal of literature suggests that it is an innovative and excellent tool that scaffolds metacognitive skills and helps challenge students' misconceptions. However, Amy was not satisfied with her students' use of or learning with the tool; some completed their research projects in a single day by answering embedded questions, some told her they liked the tool because they worked with computers, and others said they liked to chat online with friends sitting right next to them. Those responses surprised and disappointed Amy because she expected the Web-based tool to increase opportunities for students to inquire, to generate hypotheses and predictions, and to otherwise engage in observing as young scientists. What went wrong?

Despite an ongoing debate regarding inquiry approaches in science classrooms, researchers concur on one thing: facilitation of inquiry-based activities is no trivial task (Barab & Luehmann, 2003; Volkmann, Abell, & Zgagacz, 2005). The challenges intensify when technology is employed; indeed, a variety of tools purported to support scientific inquiry have been proposed. During the last decade, inquiry researchers in science education have explored technological capacities to support inquiry practice [see, for example, project-based science (Krajcik, Blumenfeld, Marx, Bass, & Fredricks, 1998), modeling-based inquiry (Barab et al., 2000; Edelson, Gordin, & Pea, 1999), and classroom-based technological innovations seeking sustainable reform (Blumenfeld, Fishman, Krajcik, & Marx, 2000; Linn, Clark, & Slotta, 2003)].

Paradoxically, as conveyed in the vignette, the very tools designed to facilitate scientific inquiry may hamper it. Technology tool failures in science classrooms have been attributed to the lack of guidance for teachers (Anderson, 1995; White & Frederiksen, 1998), unattainable goals for students (Schneider, Krajcik, & Blumenfeld, 2005), complex classroom settings involved with diverse contextual factors and school culture (Cuban, 2001; Papert, 1987), and the gap between the ideal and the reality (Anderson & Helms, 2001). Researchers and practitioners have attempted to clarify when technologies support students' scientific understanding, which activities and support facilitate students' inquiry processes, and how to sustain technology-enhanced innovations in everyday science classrooms. The purpose of this paper is to examine the findings and implications of research on science inquiry tools on classroom teaching and learning practices. We summarize research on inquiry tools and present a framework for teaching and learning in technology-enhanced, inquiry-based science classes.

Tools for Scientific Inquiry

Among the many debates on inquiry in teaching and learning, researchers have reported that well-designed science tools help to provide authentic learning environments (Edelson, 2001), foster students' motivation (Mistler-Jackson & Songer, 2000), and support multiple representations of knowledge (Sadler, Whitney, Shore & Deutsch, 1999). In particular, researchers have explored the technology's potential to overcome the barriers to implementing classroom-based inquiry. For example, 3-D animations and modeling tools have enabled students to find evidence and manipulate variables efficiently by visualizing scientific concepts dynamically and authentically (Barab et al., 2000; Jackson, Krajcik, & Soloway, 2000). Invention and distribution of handheld technology has helped students to collect field data (e.g., temperature), as well as to input and manipulate data immediately (Norris & Soloway, 2003). Furthermore, access to the World Wide Web enables students to locate information shared among experts (Hill & Hannafin, 2001), while the convenience of electronic mail and bulletin boards helps to promote communication among peers, teachers, scientists, and community members (e.g., see the Science Controversies Online Partnerships in Education [SCOPE] project[2]).

However, while the potential of technology has been heralded by its proponents, it may not facilitate the engagement and learning valued by the scientific community. Students using the World Wide Web, for example, have experienced difficulties reaching learning goals and understanding scientific concepts. They often tend to simplify inquiry tasks and seek “right” answers rather than to investigate deeply (Wallace, Kupperman, Krajcik, & Soloway, 2000).

In the following section, we examine competing perspectives on technology in supporting student learning, teaching practices, and learning context in science classrooms. For clarity and convenience, these sections are isolated; in practice, however, student learning, teaching practice, and learning context are interdependent, as evident in the framework we propose.

Student Learning

We analyze three assertions related to technology-enhanced tools for student learning through inquiry: (1) cognitive tools support mindful investigation of driving questions; (2) tools

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[2] http://scope.educ.washington.edu/

serve as metacognitive scaffolds for building and revising scientific understanding; and (3) tools support collaborative construction of scientific knowledge.

Supporting Scientific Problem-Solving. Several researchers suggest that technologies *can* transform learning both qualitatively and quantitatively (Jonassen & Reeves, 1996; Lajoie, 2000; Pea, 1985; Salomon, Perkins, & Globerson, 1991). According to advocates, cognitive tools—"technologies, tangible or intangible, that enhance the cognitive powers of human beings during thinking, problem-solving, and learning" (Jonassen & Reeves, 1996, p. 693)—help students to invest their attention in, and spend time on, problem-solving processes (Pea, 1985). For example, Stratford's (1997) analysis of several studies undertaken in pre-college science classrooms indicates that students using STELLA and Model-It were able to think deeply about types of, and relations among, variables associated with a phenomenon. Stratford also asserts that alternative technology roles (i.e., modeling, simulation, running simulation) involve different cognitive demands and operations. Through mindful engagement, technologies serve as students' "intellectual partners" to support higher-order thinking skills (Salomon, Perkins, & Globerson, 1991).

However, surprisingly little is known about how students and teachers actually utilize different tools, solve problems, and inquire in everyday, technology-enhanced science classes. Nor have we successfully established how (or if) enacted inquiry teaching-learning processes differ from conventional science approaches. For instance, careful study of problem solving across time, by delivery medium and with respect to epistemological lens, has proven elusive and problematic (Bruner, 1960; Dewey, 1916; Gagné & Briggs, 1974; Piaget, 1976). In some cases, instructional materials have been created by professional designers who have little knowledge about science problem-solving processes (Jonassen, 2000). Only recently have researchers in the field of instructional technology become invested in the design of learning environments that facilitate students' knowledge construction (Jonassen, 1991; Kozma, 1994, 2000)

Providing Metacognitive Scaffolds for Science Learning. According to proponents, computer tools help students to confront and address scientific misconceptions needed to revise and reconstruct their understanding (von Glasersfeld, 1989, 1993). Linn, Clark and Slotta (2003) propose four principles for designing inquiry tools to support students' knowledge construction: "making thinking visible, making science accessible, helping students learn from each other, and promoting lifelong learning" (p. 524). They further argue that students naturally build "multiple conflicting ideas about virtually any scientific phenomenon due to their everyday experience, compounding evidence, and naïve prior knowledge" (p. 518). Thus, according to its creators, WISE (Web-based Inquiry Science Environment) helps students to revise misconceptions by providing metacognitive supports such as inquiry maps for guided inquiry activities, hints on inquiry questions, and evidence pages with relevant scientific ideas and examples.

Other researchers have attributed improvement in students' scientific conceptions and their resolution of misconceptions to metacognitive supports embedded in computer tools. White and Frederiksen (1998, 2000) report that in 7^{th}-grade to 9^{th}-grade physics classes, students who used the ThinkerTools Inquiry Curriculum facilitated by *Inquiry Cycle* (i.e., *Reflective Assessment*, a process-oriented inquiry procedures containing *Question, Predict, Experiment, Model,* and *Apply* components) dramatically improved their conceptions about motion. Similarly, Wu, Krajcik, and Soloway (2001) report that 11th graders using eChem (a computer-based visualizing tool that links conceptual ideas and visual representations on molecular models) significantly improved their understanding of chemical representations by following a guiding process embedded in the tool—that is, *Constructing, Visualizing,* and *Analyzing* molecular structures and chemical formulas.

Contradictory research findings have also been reported. In one study, Land and Hannafin (1997) examined patterns of both tool usage and understanding among 7th graders using ErgoMotion to study, speculate on, and test hypothesized relationships between force and motion. Embedded tools were augmented with a series of metacognitive guides and prompts designed to assist students in planning and conducting their inquiries. Low-performing students persisted in undifferentiated "point and click" steps to select values and initiate a simulation and failed to evolve either an inquiry strategy or a conceptual understanding of the relationship among the constructs. In effect, some students were unable to solve higher-level problems even using carefully designed, evaluated, and scaffolded inquiry tools.

Oliver and Hannafin (2001) studied how 8th graders used KIE's (Linn & Slotta, 2000) Sensemaker to locate and categorize Web resources and Mildred tools metacognitively to frame and solve problems associated with earthquake engineering. Students developed "partial ideas… [but] understanding of earthquake engineering problems did not improve to canonical or conventional models" (p. 28-29). These results typify the discrepancies often reported between controlled classroom research and research done within ongoing classroom flow and activity. In everyday classroom contexts, many factors influence classroom implementation (e.g., students' developmental readiness, teacher roles, teaching practices, classroom cultures, standardized tests, and administrative policies).

Facilitating Collaborative Construction of Scientific Knowledge. Advocates have suggested that technologies support learning as social practice in inquiry-based science classrooms. Inquiry tools can cultivate dialectical learning processes through cooperation with more (and less) knowledgeable peers by, for example, searching for topics, posing questions, and commenting on other students' postings. Newman, Griffin, and Cole (1989) characterize such systems as "construction zones." Scardamalia and Bereiter (1991), for example, developed and refined CSILE (Computer-Supported Intentional Learning Environments) to its current iteration, known as *Knowledge Forum*—a Web-based inquiry tool designed to foster students' knowledge co-construction. In their research, Scardemalia and Bereiter note that 5th- and 6th-grade students using CSILE to foster students' knowledge co-construction to learn about endangered species and fossil fuels were able to generate meaningful questions that guided further investigation and communication.

More recently, researchers have scaffolded students' social interaction with both people and Web-based resources (Hoffman, Wu, Krajcik, & Soloway, 2003; Recker, Walker, & Lawless, 2003). Hoffman et al. (2003) explored how 6th graders employed the World Wide Web to construct content knowledge in two science classes. During a 9-month study of scaffolded inquiry, they observed eight pairs of students using *Artemis* to support their online search from two science classes. Results indicated that students who actively engaged in online inquiry with scaffolded strategies (*Ask, Plan, Tools, Search, Assess, Write, Synthesize, and Create,* p. 337) were able to develop deeper and more accurate understanding about the content than those who did not.

So, while the potential of classroom-based scientific inquiry tools is compelling, contradictory evidence exists and implementation barriers and issues remain to suggest that the promise has yet to be fulfilled. Research is needed to clarify (1) how students collaboratively build and revise their understanding with assistance from diverse types of scaffolding, (2) how technological affordances influence collaborative knowledge construction processes, and (3) how these processes differ in terms of subject areas, teachers, ages, and classrooms.

Teaching Practice

Considerable emphasis has been placed on teachers' roles in inquiry-based classrooms. Some researchers (e.g., Chinn & Malhotra, 2002) suggest that schools and teachers often fail to understand and implement the central features of scientific inquiry. Perhaps this stems from divergent views on teaching science: traditional perspectives regard scientific content and process as separate constructs, while standards (e.g., NRC, 1996, 2000) promote content and process as integrated (Edelson, 2001). Similar challenges and issues emerge during classroom-based, technology-enhanced science inquiry. We examine two critical areas associated with this problem: (1) teacher roles and classroom-based inquiry, and (2) teacher's inquiry experience and knowledge, and professional development.

Teacher Roles. For decades, researchers have underscored the importance of teachers' roles and knowledge (Crawford, 2000) and the impact of their beliefs on teaching practices (Brickhouse, 1990; Bryan & Abell, 1999; Nespor, 1987). Teachers play pivotal roles in inquiry-oriented classes as they select and design tasks, facilitate student activities, and assess their work (Keys & Bryan, 2001). In order to interpret and promote these essential roles, researchers have stressed the need for examining relationships between teacher beliefs in learning and teaching, teacher roles and student learning, and their classroom practices (Bryan, 2003).

Concurrently, research has also confirmed that reform-based enactments for inquiry are successful when teachers actively participate in designing inquiry-oriented curriculum, implementing innovations, and reflecting collaboratively on their beliefs and practices (Lynch, 1997; Parke & Coble, 1997; Tobin & LaMaster, 1995). Lynch's (1997) study of 25 beginning teachers, who collaboratively developed curriculum based upon their discussion, interpretation, and evaluation of the NRC Standards, indicated the critical need for teachers to carefully examine reform documents and make concrete connections between inquiry goals and their teaching activities.

According to Chinn and Hmelo-Silver (2002), however, “many inquiry activities found in schools fail to capture important characteristics of authentic scientific inquiry” (p. 171). Findings from classroom-based studies indicate that, due to the open-ended nature of inquiry, it has become increasingly challenging to be a “good” teacher in inquiry-oriented science classrooms. Teachers are expected to be flexible to students’ individual needs, unpredictable classroom situations, and alternative explanations (Wallace, 2002). Crawford’s (2000) detailed study of a successful high school ecology teacher revealed that inquiry demands more from teachers than traditional lecture or exploratory classes. The innovative, successful teacher in her study played multiple roles (motivator, diagnostician, guide, innovator, experimenter, researcher, modeler, mentor, collaborator, and learner) to support student-oriented inquiry practices. While these attributes are challenging to describe adequately, they may prove even more difficult for teachers to envision or apply in everyday classroom practice.

Many researchers concur that the major barriers to classroom inquiry are teachers’ lack of time, resources, and technical support, as well as pressure from administration on standardized testing (e.g., Anderson & Helms, 2001). Anderson (1995; Anderson & Helms, 2001) pinpoints several constraints science teachers face in initiating and sustaining inquiry in their classrooms: (a) lack of time to design and teach both content and process knowledge about inquiry; (b) conflicts between the ideal Standards and the realities of the science classes; (c) tensions between emerging teachers’ roles in inquiry classes and the typical school culture; (d) the “preparation ethic," in which teachers feel responsible for making students ready for the next level; and (e) the challenges of assisting students of different levels to focus on higher-level problems. However, few studies demonstrate ways to overcome significant challenges or address these constraints. Although many inquiry tools have been proved successful in science classes when supported by teams of researchers, these implementations are often advanced under small-scale, optimized conditions. The everyday realities of initiating and sustaining implementation are even more daunting as teachers attempt to integrate inquiry into classrooms largely unaided and independently (Fishman & Krajcik, 2003).

Teacher Experience and Knowledge. For science teachers, authentic, personal, and professional experience and knowledge both doing inquiry and doing research have proven pivotal for facilitation of students' inquiry practices. Several researchers challenged reform-based efforts for their failure to account for practical knowledge—deeply personally, highly contextualized, and influenced by teaching experience (van Driel, Beijaard, & Verloop, 2001). Furthermore, Mulholland and Wallace (2005) suggest teachers' pedagogical content knowledge requires the longitudinal development of experience as they transition from novices to experienced teachers.

Bryan and Abell (1999) conducted a case analysis of a pre-service teacher (Barbara) to investigate the process used to transform her teaching beliefs and practices. They reported that Barbara's experience as "a science learner, an elementary education student, an observer of the profession, and a professional" (p. 126) influenced how she identified and framed conflicts between vision and practice in classroom teaching. Bryan and Abell concluded that teachers' "reflective experience" (p. 121) is critical to developing professional knowledge and understanding and interpreting diverse perspectives as a teacher.

The absence of experience, in contrast, may seriously limit the quality and frequency of inquiry-based classroom activities. Windschitl (2002) studied 6 pre-service secondary science teachers as they worked on inquiry projects, discussing the nature of science and maintaining journals over 2 months in a science teaching methods course. He then observed the participants teaching *after* their 9-week course experience. Windschitl reports that teachers who had substantive scientific experience prior to the course successfully implemented inquiry activities, while those who lacked practical scientific experience were less successful. This study suggests that while professional development may help to cultivate views about scientific inquiry, it may be difficult for teachers to facilitate students' inquiry when they lack experience doing research.

Similarly, knowledge of subject matter influences teachers' use of computer-based tools. Crawford and Cullin (2004) studied 14 pre-service secondary science teachers, the majority of whom were pursuing certification in biology, while they built and verified models with *Model-It* (Jackson, Krajcik & Soloway, 2000) in a science methods course. They found that considerable scientific knowledge was needed to create robust models, to build relationships between the models, to anticipate likely student misconceptions, and to provide scientifically grounded explanations of the phenomena being modeled.

We need to explore ways of providing experiences that enhance teachers' pedagogical content knowledge and influence classroom inquiry practices. During the past decade, professional development programs have been established and research has been largely focused on format, duration, and activities of professional development programs, but few examine how (or if) technology-enhanced, inquiry-based teaching and learning activities are enacted in local classroom settings. Others have proposed approaches that help teachers to comprehend the nature of science and inquiry-based teaching [e.g., professional development distributed via online programs (Harlen & Doubler, 2004)]. We need stronger evidence of approaches that link teacher inquiry experiences and knowledge, such as those provided through professional development programs, with actual classroom teaching practices.

Technology-enhanced Classroom Environments

The uses of technology, both by teachers to teach and do science and by students to learn and inquire about science, have become core approaches to promoting scientifically and technologically literate citizens—that is, to prepare all Americans to compete in the information society (see AAAS, 1989, 1993; NRC, 1996, 2000). Responding to advances and growing demands for technology integration, researchers have proposed a multitude of technology-enhanced inquiry-oriented approaches (see, for example, Barab & Luehmann, 2003; Kim & Hannafin, 2004).

Technological advances have yielded tremendous opportunities for transforming science learning and teaching: collecting and analyzing data, modeling, and communicating results; locating and representing information in dynamic and interactive ways; and increasing the numbers of and access to computers in schools (Edelson, 2001). Based upon such affordances, scientific inquiry tools can have both literacy and pedagogical impacts. In contrast to science classes where teachers explicitly prescribe procedures to follow and content to be studied from textbooks, technology-enhanced, student-centered classes provide students with flexible opportunities to manage their inquiry processes and monitor their progress. Pedretti, Mayer-Smith, and Woodrow (1998), for example, conducted a naturalistic case study of the impact of technology on students' perceptions and learning through the TESSI (Technology-Enhanced Secondary Science Instruction) Project, a system designed to incorporate technologies into secondary science classes by providing instructional and technological support. They interviewed 144 students from science classes and reported that students identified several advantages of computer-based programs, including student-oriented learning activities, ownership over their learning pace, and awareness of “meta-learning.” One telling quote taken from their interviews underscored the metacognitive benefits: “You’re learning how to learn basically. You’re learning how to teach yourself something with the information you’re given” (p. 586).

Technology has been integrated in various ways. Benenson (2001) integrated technology into a project-based science classroom and identified its positive influence on students’ understanding of technology as content, process, and social practice. Based on his research with The City Technology Curriculum Guides project, implemented in urban elementary schools in New York City, Benenson concluded that technology should be integrated richly and broadly into the classroom and across subjects (such as science, mathematics, language arts, and social studies) rather than isolated as a subject.

Other researchers have proposed visions and rationales for technology-supported inquiry learning (Edelson, 2001; Stratford, 1997) and specific roles for computer-based inquiry tools (Barab, Hay & Duffy, 1998; Barab & Luehmann, 2003). However, we have not yet determined why and how inquiry tools work in some teaching-learning context but not others, or how diverse learners, domains, and activities interact in technology-enhanced inquiry environments. Few examples or cases are available to persuade administrators, teachers, and stakeholders of the importance of knowing *how* to support inquiry using computers and tools.

In sum, research on technology-enhanced inquiry environments suggests that technology *per se* is unlikely to support students’ inquiry processes. However, well-designed computer tools, coupled with scaffolding from experts, teachers, peers, and community members, can support students' thinking and learning about scientific content and processes. It is important to understand the relationships between and among factors likely to influence the use and effectiveness of technology tools in science inquiry.

A Framework for Teaching and Learning with Inquiry Tools

In this section, we propose a sociocultural framework for teaching and learning with inquiry tools. The framework assumes that knowledge is socially constructed (Vygotsky, 1978), that learning occurs in the process of becoming a member of communities of practice (Lave & Wenger, 1991), and that language and tools play a central role in the collaborative building of knowledge (Pea, 1993). Social constructivism provides a compelling theoretical framework for creating and analyzing learning and teaching activities in technology-supported inquiry-oriented activities in everyday classroom settings. Anderson and Helms (2001) underscore the need to organize learning contexts, students' learning, teachers' roles, and systematic factors:

> The most fruitful approaches for the future are those that are the most *holistic* and *systemic*. Scholarship must be holistic in the sense of giving *simultaneous* attention to all the many elements and perspectives that are part of the picture. They must be systemic in that attention is given to the many *interactions* among the various elements and the influence they have on each other. (p. 5)

Figure 2.1 depicts a framework for teaching science using technology-based inquiry tools in everyday classroom settings. Three dimensions are represented: the macro context (systemic reform and educational standards), the teachers' community (physical or virtual context, where teachers share expertise and mentor each other), and the micro context (classroom context, where learning and teaching occur).

Macro Context—Systemic Reform and the Standards

Macro contexts promote and frame teaching-learning activities in the science classroom. In current thinking, the macro context is shaped by several influences, including national science goals and local (e.g., school improvement plans), state (e.g., basic skill accountability), and national (e.g., No Child Left Behind [NCLB]) reform movements, as well as standards and practices advocated by professional and scientific organizations. While these initiatives each influence teaching-learning expectations, they can present competing rather than complementary influences. AAAS Benchmarks (1993) and NRC Standards (1996), for example, establish a vision for "science for all Americans," providing guidelines for learning, teaching, and professional development for science content, assessment, and supporting materials. NCLB legislation, in contrast, mandates specific assessment-accountability requirements that conflict with local and national organization priorities. Such conflicts present non-trivial teaching-learning consequences to entire school districts and schools, as well as to individual teachers, students, and educational researchers (Brickhouse, 2006). In order to advance and sustain standards-based reforms in science, the influence of both complementary and competing macro contexts must be weighed.

Successful standards-based reform efforts need to be aligned with and reflect the experience and wisdom of teachers who confront everyday barriers (Bianchini & Kelly, 2003). Successful efforts provide exemplars across diverse topics and subjects, are aligned with and grounded in scientific and pedagogical research and theory, and support stakeholders throughout the transformation process. That is, they overcome the concerns of the "atheoretical" (Shiland, 1998) and "invisible" (Rodriguez, 1997) nature of the Standards by aligning and making concrete the associated practices and supporting requirements. To do so, we need to better link the Standards' visions and components with the broader, macro-level priorities, influences, and realities of practicing teachers. While a detailed analysis is beyond the scope of this paper, it is important to recognize the macro-context's overarching impact on teaching community and classroom-level science teaching practices.

Teacher Community

During the past two decades, a myriad of national standards have been published calling for teachers to facilitate students' problem solving and critical thinking in various disciplines such as social studies (National Council for the Social Studies, 1994), mathematics (National Council of Teachers of Mathematics, 1989), science (National Research Council, 1996), and language education (National Council for the Teachers of English, 1996). In response to these calls, much attention has been placed on how to design and support science teacher communities and students of different age groups. In the following sections, we examine promises and challenges associated with supporting technology-enhanced inquiry within teaching communities.

Promise. Researchers have demonstrated positive effects of teacher communication and collaboration on affective (e.g., increased confidence and enthusiasm, DeWert, Babinski, & Jones, 2003) as well as cognitive and social domains (e.g., critical thinking and reflection, Harrington, 1992). Communities can both share ideas with policymakers at the macro level and provide a forum where knowledge and expertise are shared, supported, and distributed. Online teacher communities, for example, provide pre- and in-service teachers with support for collaborative knowledge building (online discussion), build authentic teaching experiences through technology (online cases), and enhance knowledge-management through online resources (teacher library).

Supporting collaborative knowledge sharing. Co-teaching experiences have been found to be effective in facilitating competency among beginning teachers (Roth, Masciotra, & Boyd, 1999) and in sharing instructional materials and resources (Roth, Tobin, Carambo, & Dalland, 2005). Palincsar et al. (1998) successfully facilitated community development using GIsML (Guided Inquiry supporting Multiple Literacies), where teachers collaboratively plan, develop, and reflect on their science teaching activities with a focus on heuristic-oriented and inquiry-based pedagogical strategies (e.g., *Engage, Investigate, Evaluation Explanations, and Report findings*, p. 12). The participating teachers also videotaped their teaching practices and debriefed with other teachers in the community. They concluded that such collaborating and community-building activities helped teachers to develop situated knowledge grounded in everyday teaching practices.

Technology-enhanced communities can also provide virtual opportunities where beginning teachers are mentored by experienced teachers through face-to-face and online discussions. For example, Inquiry Learning Forum is designed to help mathematics and science pre-service and in-service teachers build and share inquiry-oriented classroom activities using a Web interface organized using a classroom metaphor (Barab, MaKinster, Moore, & Cunningham, 2001). Pre-service, new, and experienced teachers collaboratively share their insights, questions, and expertise on topics ranging from classroom management to professional development.

Supporting authentic teaching experiences. Professional development efforts have been criticized for their failure to reflect authentic classroom situations and their limited impact on classroom practices (Glazer & Hannafin, 2006). Typically, in science education, such efforts focus on generic teaching strategies across diverse science domains, but fail to adequately reflect the moment-to-moment demands of everyday science teaching or to support implementation specific to science content knowledge during classroom teaching and learning (Lee, Hart, Cuevas, & Enders, 2004). When situated in their own classroom teaching practices and supported by hands-on teaching practices and pedagogical content knowledge, professional development endeavors have proven effective for enhancing teacher knowledge and changing their practices (Garet et al., 2001).

In order to help teachers expand and build upon their situated, authentic learning experiences, exemplary cases depicting teaching with inquiry tools have been provided via online teaching cases. Online cases can capture complex classroom situations and specific pedagogical strategies for particular science contents, as well as provide vivid and concrete portrayals for teachers (Kim & Hannafin, in press). Kim, Hannafin, and Kim (2004) examined goals and uses of cases for teacher education, including case studies for analyzing critical incidents, case-based projects for referring to other cases and creating one's own, and thinking engines for promoting critical thinking. Authenticity has been enhanced by capturing video of everyday science classroom dilemmas and sharing them with preservice teachers (Wong, Yung, Lam, & Hodson, 2006). Krueger, Boboc, Smaldino, Cornish, and Callahan (2004) describe *InTime (Integrating New Technologies Into the Methods of Education),* a Web-based system that provides access to captured online video, and provides case descriptions and analyses of how experienced teachers integrated technology into their everyday classroom practices.

Enhancing knowledge management. Teacher communities may also encourage and support teachers' access to online resources designed to enhance their knowledge management. Otero et al. (2005) describe the efforts of a science education faculty member who incorporated WebCT and digital cameras into her teaching. The teacher educator, who often used dry-erase boards during classroom discussions of the nature of science, uploaded pictures taken from the dry-erase boards to WebCT so that they would be available to students at any time. Through the use of these tools, knowledge management was improved for both the teacher educator and the pre-service teachers. The researchers attributed success to improved understanding of the pedagogical and situative uses of technologies for her pre-service teachers' own situations.

Challenges. Despite the calls from national standards, potential benefits of teacher collaboration identified by researchers, and the growth of online communities, few online science teacher communities have been developed or researched. Although professional development efforts have the potential to facilitate teacher communities, they often emphasize accessing online resources rather than cultivating collaborative cultures or facilitating discourse where teachers can share knowledge. Perhaps this is attributable to the time and effort needed to develop collaborative communities and the complexity of supporting efforts to teach via tool-enhanced inquiry. Increased access may simply be perceived as achievable given typical professional development constraints. In addition, teachers rarely receive credit or incentives for sharing expertise or mentoring beginning teachers through online teacher communities. Given the volume of everyday, routine teaching demands, greater priority is tacitly assigned to individual accomplishments and performance. It is necessary to signal the importance of strengthening the teaching community by establishing appropriate incentives and rewards.

Research is needed to address spurious connections between and among macro contexts and teacher communities. The misalignment between inquiry processes, which are valued by the science education community, and competing reforms are manifested in different curricular priorities, teaching-learning processes, and assessment methods. Likewise, it is problematic to design and implement meaningful professional development for teachers who lack adequate experience with and facility in inquiry process and tools. However, change may be most difficult to advance in teaching communities where, swayed by competing priorities or different epistemological beliefs, inquiry simply is not valued sufficiently to attempt or sustain associated pedagogy (Chan & Elliott, 2004; Ertmer, 2005). Research is needed to examine the roots of resistance to conceptual change, as well as approaches to reconcile inquiry epistemic beliefs and practice.

Micro Context—Technology-supported Inquiry Class

Micro contexts are the specific classroom settings where students construct their knowledge with more capable others (Vygotsky, 1978), such as inquiry tools, teachers, and peers (Kim & Hannafin, 2004). In this section, we examine three types of micro-context interactions in technology-supported inquiry classes and the scaffolds that support these interactions.

(a) Student-Tool Interaction

Promise. Several approaches have been proposed to support interactions between students and tools in science classrooms, including technology-supported inquiry learning (Edelson, 2001), project-based learning (Krajcik, Blumenfeld, Marx, Bass, & Fredricks, 2001), and scaffolded knowledge integration (Linn, Clark, & Slotta, 2003). As detailed previously, students can generate ideas by exploring with driving questions, test hypothesis by manipulating variables and factors, and distribute their own knowledge to others through Web-based platforms.

Researchers have identified functions for scaffolds embedded in tools: (1) conceptual scaffolds help students to understand essential ideas and theories; (2) metacognitive scaffolds assist students in monitoring learning processes and reducing cognitive overload; (3) procedural scaffolds assist students to structure their tasks and necessary steps; and (4) strategic scaffolds help students to find alternative problem-solving strategies (Hill & Hannafin, 2001). Reiser (2004) further notes that tool-based scaffolds help to structure and problematize student tasks. Tools can be used to “decompose” complicated inquiry tasks and procedures (such as examining hypotheses and manipulating variables), thus reducing extraneous cognitive load in order for students to focus on core concepts and monitor their inquiry processes. Technology tools can problematize and challenge ideas by posing question prompts and providing feedback to encourage students to formalize their thinking and examine multiple perspectives.

Challenges. Despite the abundance of tools and affordances to support inquiry, results of classroom-based implementations have yielded mixed results. While some researchers have reported promising data (Hoffman et al., 2003), others have identified difficulties in students’ generating, manipulating, or distributing knowledge (Edelson, Gordon, & Pea, 1999; Oliver & Hannafin, 2001; Kuiper, Volman, & Terwel (2005), in their meta-analysis of six years of research on elementary and middle school students’ use of the World Wide Web, identified prior knowledge, attitude, gender, and age as salient factors enhancing or hampering students’ investigations using the Web.

Others have reported increases in student motivation for tasks when using technology in science classrooms (Mistler-Jackson & Songer, 2000; Pedrettis, Mayer-Smith, & Woodrow, 1998). Yet, many students—especially those who lack confidence in self-directed learning—experience difficulties inquiring individually and depend on explicit traditional teacher direction (Ng & Gunstone, 2002) for guidance in tool use. Increased student motivation may be necessary, but it not sufficient to promote effective use of tools to support inquiry.

When tool-based inquiry activities are not properly scaffolded, students encounter various problems, such as cognitive overload and difficulties reading online text. Wallace, Kupperman, Krajcik, and Soloway (2000) studied how 6th graders from two classes access, locate, and utilize online resources during several days of ecology activities involving student question-formation, Web and library searching, journal keeping, and presenting research results. Students tended to seek out Web pages that contained “answers” and preferred to find the answers quickly rather than to examine information and develop a deeper understanding of a concept. The researchers attributed superficial use of technologies to the Web browser design that allowed students to access unlimited resources without guidance. They conclude that it is essential that student activity be supported through conceptual and procedural scaffolds embedded in the Web tool, such as maintaining search records, providing key terms, and identifying activity-appropriate online materials.

Little is known regarding the circumstances during which student-tool interactions are meaningful and constructive, how individuals or groups of students utilize them, and the individual strategies enacted during tool-supported inquiry learning. While authors have cited tool use barriers (e.g., limited metacognitive capacity, limited time and resources for students to become immersed in inquiry processes, and poorly designed tools), little evidence exists that documents how these barriers influence student-tool interaction or explains how to overcome them (Kim & Hannafin, 2004). Finally, studies examining tool use during classes are often context-specific (class, school, community) and have rarely been examined in similar classroom settings. Students’ tool use can vary dramatically depending on the school contexts and teacher characteristics (Songer, Lee, & McDonald, 2003). Research is needed to examine the impact of school context and teacher characteristics, as well as the generalizability of findings, related to student-tool interaction in everyday science inquiry classrooms.

(b) Teacher-Student Interaction

Promise. During technology-enhanced science inquiry, teachers scaffold student activity in two key ways: (1) by providing question prompts that challenge students' thinking and motivate the students to do inquiry, and (2) by monitoring students' learning processes. Teacher coaching and questioning are especially useful when students—especially those with limited prior knowledge—face conflicting evidence. Land and Zembal-Saul (2003), for example, studied how technology-supported scaffolds embedded in Progress Portfolio were used by four preservice teachers studying scientific conceptions about light. The pre-service teachers documented their inquiry processes by creating and saving artifacts (e.g., graphs, pictures, explanations, and evidence). Participants were best able to reflect on and articulate their knowledge when instructors helped them to attend to important variables they overlooked using only technology-based scaffolds, to plan experiments and investigate concepts, and to clarify confusing ideas.

Teachers can also monitor students' technology-supported inquiry activities by asking questions about and confirming progress. Wallace (2002) examined how a high school teacher planned and implemented Internet-supported curriculum activities in nuclear chemistry. Using teacher interviews as well as video- and audio-taped classroom activities accompanying field notes, four salient teacher-student interactions were identified: monitoring, short content interactions, extended content interactions, and social exchanges. Among the interaction forms, teacher monitoring occurred most frequently via questions such as "Are you finding what you need?" or "Are you doing okay?" (p. 473).

Challenges. Despite ongoing calls for student-centered learning (NRC, 1996, 2000), everyday science classroom teaching and learning practices still confront challenges and dilemmas (Anderson & Helms, 2001). Teachers continue to struggle in enacting classroom-based science inquiry due to lack of support, time, resources, and student management skills—especially when they lack extensive content knowledge, pedagogical-content knowledge, and substantive prior experience in technology integration. Scientific knowledge, like other kinds of knowledge, may also be highly situated. In Wallace's (2002) study, the high school teacher voiced frustration while planning due to the overwhelming amount of information available on the unit topic (radiation). Although the teacher had fairly extensive formal science preparation, having majored in biology and minored in chemistry, she lacked extensive knowledge about radiation, which compromised her confidence in guiding students' investigations.

Several issues require further study. Few researchers have examined approaches to balancing technology and teacher scaffolding in technology-supported inquiry classes. Teachers may undermine the very inquiry processes they seek to cultivate. It is unclear how much teachers do (or should) direct students' tool use during their inquiry processes.

Recent research has underscored the role of teachers as knowledge co-constructors with students in inquiry classes (Windschitl, 2005). In her vivid description of a successful high school ecology class, Crawford (2000) identifies ten critical roles for teachers in inquiry classrooms: motivator, diagnostician, guide, innovator, experimenter, researcher, modeler, mentor, collaborator, and learner. However, research findings provide little guidance as to teacher facilitation of student-centered collaborative inquiry. Exemplars are needed that manifest diverse teachers roles in generating questions, revising misconceptions, collecting and analyzing data, drawing and warranting conclusions, and collaborating with peers and experts. Both the classrooms and dilemmas facing teachers in urban settings differ fundamentally from those in rural or suburban schools (Settlage & Meadows, 2002; Songer, Lee, & Kam, 2002; Songer, Lee,

& McDonald, 2001). In addition, urban teachers face additional challenges to employing inquiry tools due to the lack of infrastructure, large class sizes, and limited time for planning their lessons.

(c) Teacher-Tool Interaction

Promise. In technology-supported inquiry classes, teachers may modify how they use inquiry tools based on their epistemological beliefs, traditional classroom practices, or perceptions of students' needs and interests. Iiyoshi, Hannafin, and Wang (2005) noted that tool users create "specific configurations … deemed uniquely appropriate to address a particular learning need" (p. 292) that differ from those for which they were developed. Likewise, other researchers have emphasized the importance of tools that afford opportunities to customize and modify inquiry tools in accordance with teacher and student interests, teaching and learning styles, and specific classroom needs (Linn, 2003; Williams & Linn, 2002).

While tool extensibility affords significant flexibility to customize inquiry, tool use modifications can also compromise the very processes they are designed to promote. During classroom implementation of the Jasper Woodbury series, designed to facilitate mathematical problem solving among middle-grade students, Bransford and his colleagues (Barron, Bransford, Campbell, Ferron, Goin, Goldman et al, 1992) noted that teacher customization often supplanted the problem-solving pedagogy with more familiar didactic, procedural methods. While well received and highly rated by teachers, Jasper implementation could not facilitate the student-centered problem-solving processes (e.g., problem definition, identification and collection of related evidence, analysis, and resolution) that its tools were designed to engender.

Challenges. We need to further examine issues such as the "authority" of Web-based materials (Wallace, 2004, p. 477). Despite the unprecedented number and availability of Web-based materials, guidelines, and lesson plans, validated criteria for evaluating their accuracy and quality are lacking. This issue becomes especially problematic for teachers who lack expertise with inquiry tools. Additionally, when teachers select and customize technology tools for their own purposes, competing macro-level and community influences may become manifest. For example, inquiry tools developed by different researchers and practitioners for their unique purposes often embody both particular activities and assessment criteria related to student inquiry. These activities and criteria may reflect similar, or vastly different, perspectives than those of the teacher. Using Belvedere software, Toth and his colleagues (2002) found students' inquiry activities were more reflective and specific where assessment rubrics specified criteria for "data collection, evaluation of information collected, overall linguistic quality of reports, [and] quality of peer review presentation" (p. 270). In contrast, SCI-WISE helps students to practice inquiry processes using the Inquiry Cycle (White, Shimoda, & Frederiksen, 2000). The assessment method, called the Reflective Assessment Process, focuses on "understanding, performance, and social context" of the student's research (White & Frederiksen, 1998, p. 25). Without close study, the differences in assessment focuses are not readily apparent using typical search engines. Further, the extent to which these practices align with classroom, community, or meta-level assessment priorities will inevitably vary. Rubrics and guidelines are needed for teachers to align teaching and assessment practices with relevant standards.

Closing Thoughts

We have examined opportunities and promises associated with technology-supported inquiry classrooms in the light of student learning, teacher practices, and classroom environments. We have also described the gaps between research and practice that impede achieving these promises. Based on our critical review, we have proposed a pedagogical framework for teaching and learning with inquiry tools that can open further discussion and guide future research on teaching with inquiry-supported tools.

Unfortunately, the pedagogical framework manifested in Figure 2.1 resembles *the ideal*; another pedagogical framework, presented in Figure 2.2, mirrors the current state of practice in technology-enhanced inquiry classes. In contrast to the ideal framework, where teacher communities and micro contexts are embedded in the macro context and where the micro context is fully influenced by the teacher community, the reality framework presents three dimensions (macro context, teacher community, and micro context) that partially intersect with each other. Reasons for the lack of alignment vary.

In many cases, the expectations valued for teachers in school districts do not match with the visions enacted by the standards. Thus, the activities in many teacher communities emphasize the acquisition of certain skills and do not reflect the broader goal of a macro context, which is student-centered and process-oriented.

Next, the micro context (classroom) is influenced not only by teacher community, but also by other factors, such as school culture, parents, and students' values and characteristics. However, such factors often can be contradictory to the macro context. As Cuban (2001) noted, school culture is heavily grounded in the long history of direct instruction, in which the idea of teachers as knowledge sources who transmit knowledge to students is prevalent.

As a way to bridge the gap, we have examined promises and challenges associated with each dimension in the framework and proposed areas and questions for future studies. From this pedagogical framework, the interactions among the standards, teachers' community, and classroom contexts are key to exploring the role of technologies. It is not the innovative technologies *per se* that have an impact on students' learning, but the interactive and iterative learning environments.

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FIGURES

Figure 2.1. A pedagogical framework for teaching and learning with inquiry tools (Theoretically ideal framework)

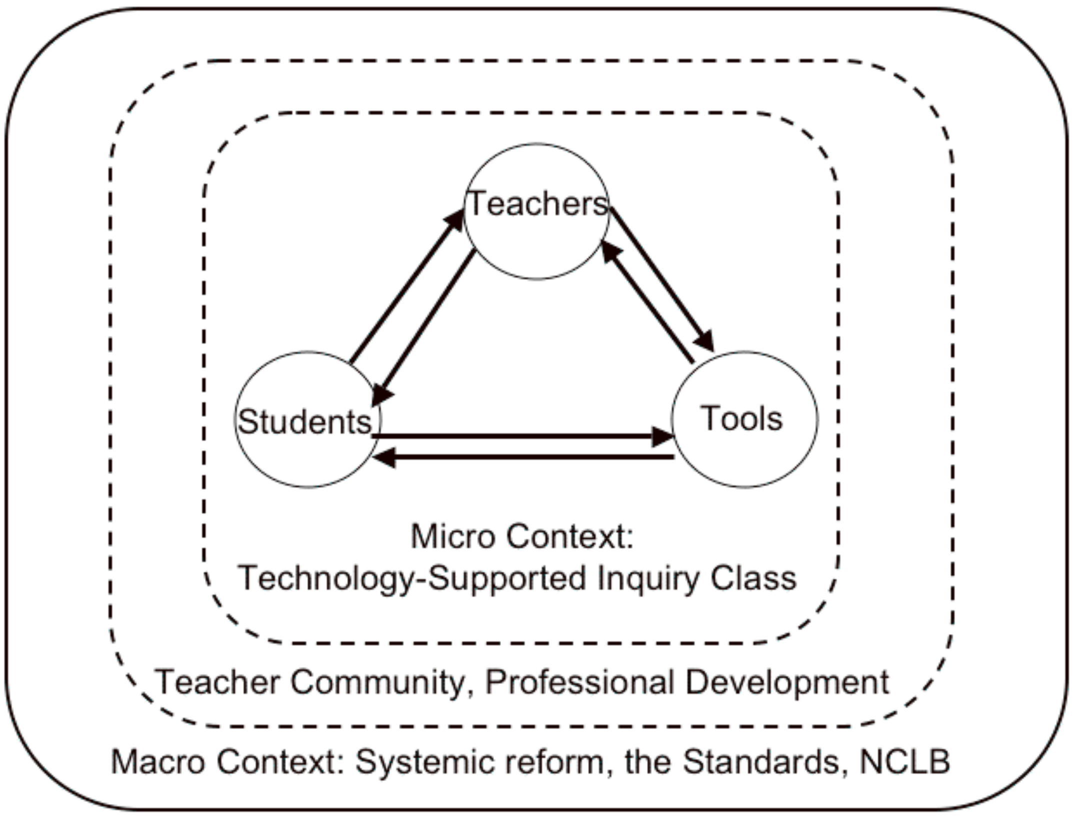
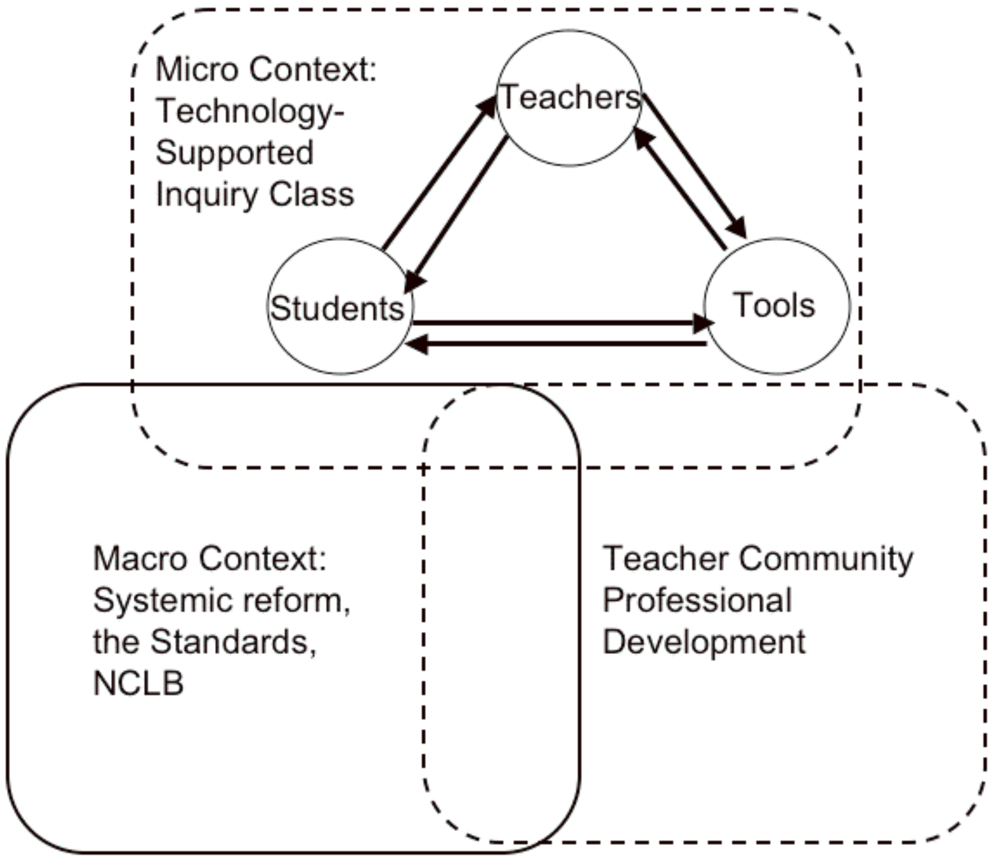


Figure 2.2. A pedagogical framework for teaching and learning with inquiry tools in reality (State of practice framework)



CHAPTER 3

PRELIMINARY STUDIES

The research questions and design reflected the researcher's experience and the findings from three preliminary studies based on progressive focusing (Glaser & Strauss, 1967). The preliminary studies were conducted from Fall 2003 to Spring 2004; their purposes were to better understand the research site and to revise initial research questions. Research problems, participants, methods, findings, and implications of each case study are discussed.

Case Study 1

The first case study was conducted to examine the interaction between an individual student and Web-based inquiry environments (Figure 3.1). During October of 2003, a 7th-grade student utilized three WISE (Web-enhanced Inquiry Science Environments) projects during weekly extra-curricular activities. The student was selected because she characterized herself as being very interested in using technologies and in investigating scientific topics related to her daily experiences (pre-interview, 10/6/2003). The researcher, as a participant observer, helped her to find and solve scientific problems using the WISE inquiry tool and to think aloud during the problem-solving processes and conducted interviews prior to and following each meeting. The researcher also recorded audio and video during the weekly meetings and wrote field notes immediately after the meetings. Interview transcripts and field notes were analyzed promptly after each meeting with the student as the unit of analysis. However, the analysis did not yield in-depth data because the participant was not trained to think-aloud or express her opinions during interviews.

Figure 3.1 represents the research problems, context, inquiry tools, and procedures of the 4-week case study; Table 3.1 depicts the student activities, WISE inquiry project, and data sources for each activity.

Figure 3.1. Case Study 1

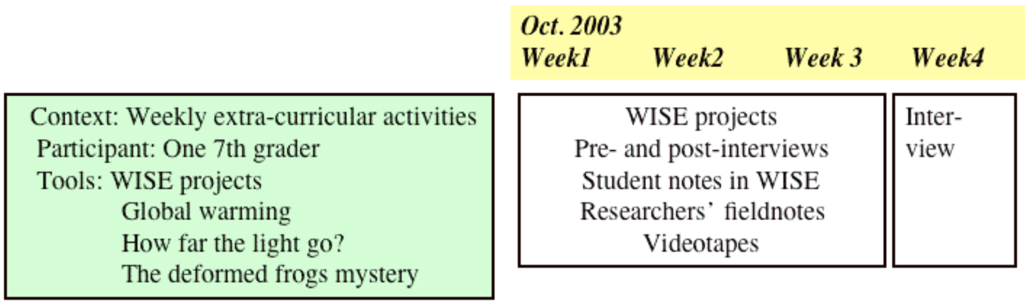


Table 3.1. Data collection procedures in Case Study 1

	Student activities	***Inquiry Project***	***Data Collected***
Week 1	Pre-interview Using the project Post-interview	Global warming	Pre-interview (audio) Observation (fieldnotes, video) Students' answers in WISE notes Post-interview (audio)
Week 2	Pre-interview Concept map Using the project Post-interview	How far do light go?	Pre-interview (audio) Observation (fieldnotes, video) Students' answers in WISE notes Post-interview (audio)
Week 3	Pre-interview Concept map Using the project Post-interview	The deformed frogs mystery	Pre-interview (audio) Observation (fieldnotes, video) Students' answers in WISE notes Post-interview (audio)
Week 4	Interview	N/A	Interview (audio)

Both substantive findings and methodological issues emerged from the first case study. First, the student spent a great deal of time exploring scientific topics in which she was initially interested and believed to be important (e.g., global warming, science fair). Katie regarded global warming as a serious issue, and thus chose to deeply investigate its causes and effects:

> Because the whole earth can sink of flooding. Maybe in a hundred years, thousand years, it can cause the earth to sink… whole earth to sink… which can cause because people won't be on earth any more because land and animals won't be on earth any more because of the land disappearing. (post-interview, 10/6/2003)

She also used WISE-structured activities and notes to guide her scientific inquiry and to reflect on her own thinking (e.g., she wanted to check her answers in the WISE notes or previous activities to solve subsequent problems). Thus, the initial study confirmed the relevance of the WISE problem pool as relevant to student inquiry interests and the usability of WISE affordances by students to support their inquiries.

However, methodological problems were also apparent. First, it proved challenging for the researcher to collect in-depth data from the 7th grader who had difficulty "thinking-aloud" as she worked alone. The weekly extra-curricular activities designed by the researcher for the study were not well-aligned with the student's individual interests or with the classroom curriculum. Therefore, the procedures were revised accordingly and implemented in the following study (Case Study 2) as students worked in groups during scheduled class time.

Case Study 2

The second case study was designed to identify both individual cognitive growth indicators and evidence of collaborative problem solving in classroom settings (Figure 3.2). In November 2003, the study took place over a three-week period in two project-based, elective classes. During the seven session project over three weeks, eight 8th graders participated in the study and used *Genetically Modified Food*, one of the WISE Web-based projects. The technology-based project consisted of three major assignments: (1) exploring the WISE project, answering questions in the WISE notes, and developing ideas on genetically modified foods; (2)

creating PowerPoint slides to defend positions[1] assigned by the teacher; and (3) presenting their arguments and defending their positions. Figure 3.2 represents the problems addressed, context, number of participants, inquiry tools used, and procedures employed during the seven sessions.

The researcher collected video data while the participants engaged problems using the WISE tools and presented and defended their ideas. The researcher also audio-recorded the individual interviews, which were conducted following completion of the study. The researcher's role was again that of participant-observer. The researcher observed the students' activities daily from 2:40 to 3:45 pm for the full three weeks and interacted with students by asking questions for clarification and providing technical help. Table 3.2 summarizes the procedures, the inquiry project, and data collected.

[1] The teacher assigned each group of two students one of the following positions: in favor of organic foods, against organic foods, in favor of genetically modified foods, and against genetically modified foods.

Figure 3.2. Case Study 2

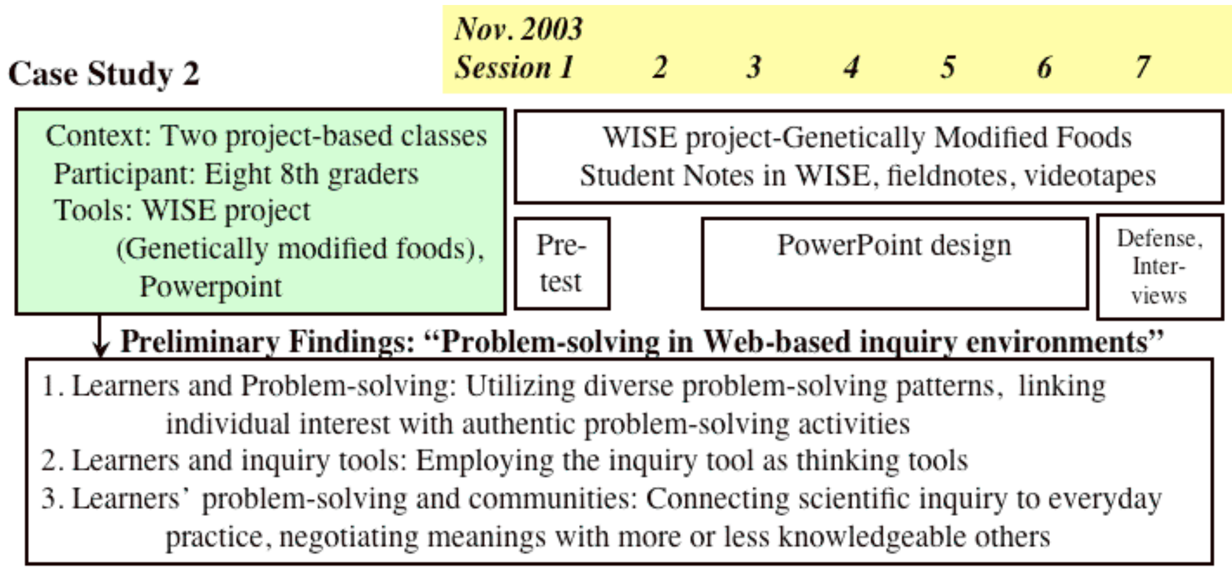


Table 3.2. Data collection procedures in Case Study 2

	Student Activities	***Inquiry Projects***	***Data Collected***
Session 1	- SCOPE Pre-test - Project introduction - WISE demonstration - Students registration - WISE Activities (1-3)	*Genetically Modified Foods*	- Pre-test - Students Notes in WISE
Session 2	- WISE Activities (4-6)		- Students Notes in WISE
Session 3	- WISE Activities - PowerPoint design		- Students Notes in WISE
Session 4	- WISE Activities - PowerPoint design		- Students Notes in WISE
Session 5	- PowerPoint design		- PowerPoint
Session 6	- PowerPoint design		- PowerPoint - Video (students activities)
Session 7	- Student presentation and defense		- PowerPoint - Video (students presentations and discussion)
Follow-up	- Individual interview		- Audio (interview)

Similar to the first case study, data from the second study were initially analyzed during and immediately after collection, and the unit of analysis was the individual student. Consistent with the first two steps of Strauss and Corbin's (1998) data analysis procedures, the researcher transcribed and coded the interviews to find common themes within and across participants via microscopic examination and open coding.

Findings from the second case study suggested that students employed divergent problem-solving strategies and experienced difficulties both thinking as “little scientists” and using the WISE projects. Based primarily on observations and student archival data, we identified five problem-solving patterns: Right-answer students, trial and error students, negotiators, reasoners, and inquirers. [See Kim & Hannafin (2005) for detailed descriptions of each pattern in Appendix A]

Right-answer students simply tried to find the correct answer to the problem under investigation. *Trial and error students* surfed across a great deal of information without reflecting on their positions or developing their own ideas on the topic. They occasionally encountered useful information, but their strategies did not transfer to other problem-solving contexts. *Negotiators* continuously checked their answers and compared their findings and problem-solving processes with those of other people or resources. These students were sometimes good inquirers, such as when they reconstructed their ideas and identified further problems to investigate. *Reasoners* monitored and diagnosed their thinking and learning processes, tending to think deeply about scientific topics and modify their opinions. In contrast to trial-and-error students, reasoners keenly examined problems and tried to avoid making the same mistakes in subsequent investigations. *Inquirers* were both good reasoners and effective communicators, exhibiting a great deal of intrinsic motivation to explore scientific problems. One student reported wanting to become a geologist. He successfully found authentic problems and spent a great deal of time investigating them. During the study, for example, he collaborated with his partner to study how genetically modified foods are related to allergens.

The results also indicated that "doing inquiry" with technology required students to link inquiry problems to their own experiences and to seek opportunities for scaffolding from various sources—peers, teacher, and technology. Some participants identified sub-topics based upon their interests and made stronger arguments than did those who did not relate their study personally to genetically modified foods. Consistent with the first case study, participants who found authentic problems (e.g., whether or not they should buy organic food, whether or not they are willing to eat genetically modified foods) tended to spend more time finding evidence and justified their positions more effectively.

Case Study 3

Case Study 3 further investigated factors that influence students' problem-solving processes and strategies during Web-enhanced science learning. Whereas Case Study 2 focused on students' cognitive processes and problem-solving strategies at individual and group levels, the purpose of the third case study was to identify and analyze factors that influenced students' inquiry processes using WISE tools.

During February 2004, the study was conducted over a three-week period with the same teacher but different students. Eleven 7th graders used WISE's *Ocean Stewards* project to complete three major assignments: (1) explore the project, answer questions in the WISE notes, and develop ideas on marine biology; (2) use PowerPoint to create a grant proposal to fund students' studies; and (3) present and defend their own and evaluate others' proposals. Figure 3.3 represents the research problems, context, number of participants, and inquiry tools. Table 3.3 summarizes the procedures of the three-week study, including the six class sessions, the inquiry project, and the types of data collected.

Figure 3.3. Case Study 3

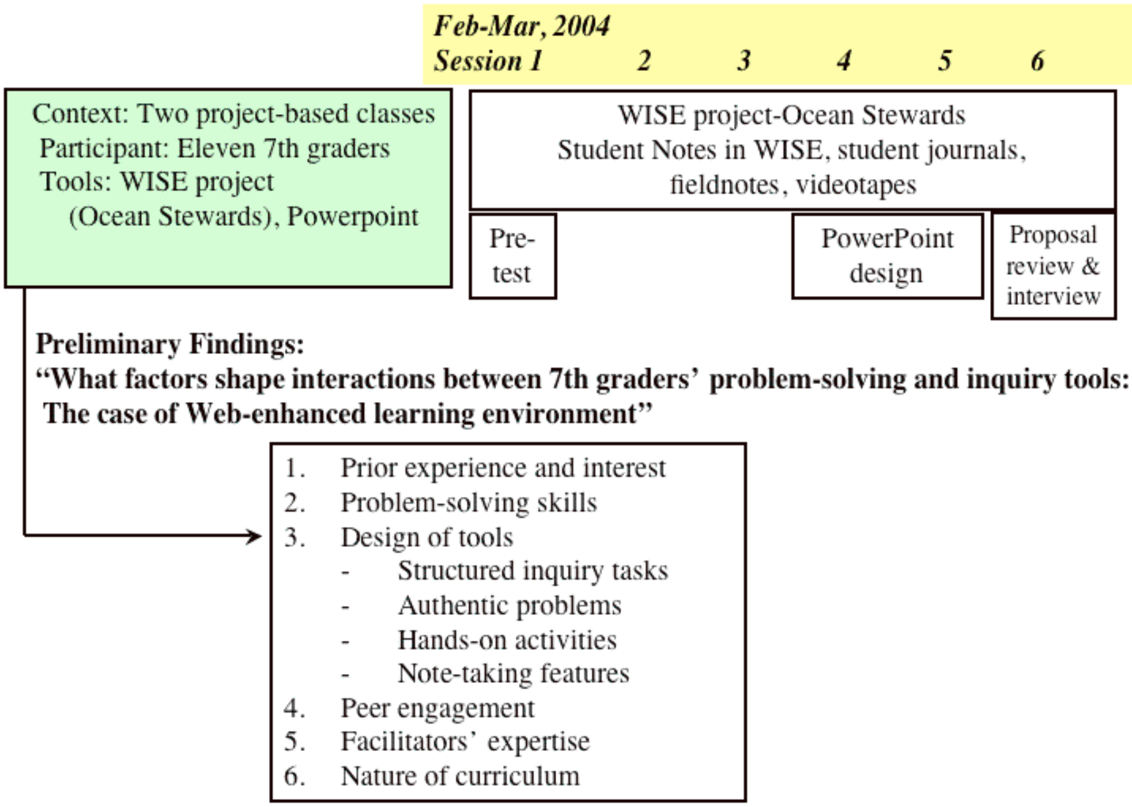


Table 3.3. Data collection procedures in Case Study 3

Class Period	***Classroom Activities***	***Tools used by students***	***Data Collected by researcher***
Session 1	- Teacher's presentation about the topic *(Ocean Stewards)* - Introduction to project - Introduction to WISE - Registration and login	- PowerPoint & Projector (teacher) - IBM computer for each student - Pre-test in WISE - WISE *(Ocean Stewards)*	- Pre-test - Electronic journals and notes saved in WISE database - Field notes
Session 2	- WISE activities	- WISE *(Ocean Stewards)*	- Electronic journals and notes saved in WISE database - Field notes
Session 3	- WISE activities - Developing criteria for evaluating research proposal - Selecting an expedition for further investigation	- WISE *(Ocean Stewards)*	
Session 4 & 5	- Create PowerPoint for research proposal - Reflect on journals and notes	- WISE *(Ocean Stewards)* - PowerPoint - Google® to find pictures	- Electronic journals and notes saved in WISE database - Field notes - Students' PowerPoint
Session 6	- Presenting proposals to peers and teacher to get funded	- PowerPoint - Evaluation form	- Individual interviews - Field notes - Students' PowerPoint

Data included field notes, audio-taped interviews conducted immediately after the activities, students' WISE notes and journals, and students' PowerPoint presentation slides. Based on the student interviews and observations, we identified six problem solving factors: (1) students' prior experience and interest with computers and scientific topics; (2) different patterns of and strategies for problem-solving; (3) design of tools that support structured inquiry tasks, authentic problems, hands-on activities, and note-taking features; (4) peer engagement that facilitates students' collaborative inquiry; (5) facilitator's expertise in encouraging students to think deeply; and (6) the nature of the curriculum, which allows the teacher and students to investigate situated problems with inquiry tools in the student-centered learning environment.

First, individual interests in scientific topics and inquiry processes influenced student interaction with Web-based inquiry tools. *Prior experience and interest* in using computers and exploring scientific topics motivated students to find problems related to their own lives and to investigate them with the WISE projects. When they selected an expedition (Archeological Findings, Loggerhead Sea Turtle Tagging, or Recreational Fishing and Sport Diving), most participants chose a topic in which they were particularly interested. In her electronic notes, Amy wrote, "We believe this expedition is important because we want to find out more about sea turtles and we would like to help them from becoming extinct," indicating her prior interest in sea turtles and her recognition of the value of the topic.

Next, consistent with the findings from the previous studies, participants employed a wide range of *problem-solving skills* as they explored scientific problems with Web-based inquiry tools. Most students were negotiators, capable of checking their answers and communicating with peers and the teacher to find better ways to solve problems. However, most students did not develop their own explanations or critically reflect on their thinking processes.

The *design of tools* is another critical factor in students' problem solving in Web-enhanced learning environments. Participants indicated that the WISE project helped them to investigate scientific issues by providing guided tasks and meaningful problems. Regarding design of tools, four sub-categories were found: structured inquiry tasks, authentic problems, hands-on activities, and note-taking features.

Regarding structured inquiry tasks, this Web-enhanced learning environment scaffolded in three ways: (1) the WISE project was incorporated into students' own open-ended task, which involved writing an expedition proposal as a group; (2) the WISE project provided five major activities[2] about which students could inquire; and (3) the students maintained online journals and wrote notes in WISE for subsequent use in writing their proposals. The structured activities helped students focus on their investigation and think further about issues associated with marine sanctuary. Participants pointed out that the WISE activities and notes assisted them to keep their records and to reflect on their progress.

The *Ocean Stewards* project incorporated authentic problems relevant to middle school students' interest in the activity, as students selected an expedition from three choices. Most participants wrote or told the researcher that they chose the topic that sounded interesting and important to them. Christine, who wanted to become an archeologist, chose to learn more about "Archeological Findings" and searched for research proposals that archeologists wrote. Bob stated that he liked this project because he believed: "Because we got to do research stuff. You are doing actually like… it's almost like a real thing. You have to do research and put presentations and show we are gonna get funded. So that was pretty cool" (post-interview, 3/4/2004). The three selections for expeditions presented in *Ocean Stewards* and the authentic

[2] 1. What are National Marine Sanctuaries? 2. Visit Our National Marine Sanctuaries 3. Marine Expeditions 4. Expeditions in Your Sanctuary 5. Planning the Expedition

nature of the open-ended project increased students motivation to explore issues related to each selection.

Some participants pointed out that the text in the *Ocean Stewards* WISE project was too long and lacked hands-on activities. Sue stated, “I didn’t like reading all the information because there were like so many stages that I went back” (post-interview, 3/4/2004). Bonnie also said, “You have to read all these pages. And I don’t like reading…. [but] I like making stuff here” (post-interview, 3/4/2004). Rather reading the lengthy text, some participants emphasized the importance of hands-on activities that could have been included in this project. Paul stated he likes hands-on activities because “when I learn new stuff, I would rather do it than having someone tell me how to do it” (post-interview, 3/4/2004). The participants actively constructed their ideas while creating their expedition proposals in PowerPoint.

Interestingly, most participants stated that one of their favorite parts in this case (Web-enhanced learning environment) was typing on their computers (note-taking feature) rather than traditional notebooks. For example, Paul related his experience as follows:

> I think because normally we would have to write all the stuff down, but we got to type it. Because we didn’t have to go back and forth from computers to notebooks. You can go straight, you can just press minimize on the notes to use information and come back to type it. So we didn’t have to go back and forth between computers and notebooks. (post-interview, 3/4/2004)

This response suggests that some of the basic features in cognitive tools, such as notes, can reduce students’ cognitive load and help them focus on higher-order thinking skills. The inquiry tools were designed to encompass various issues, such as questions of what kinds of problems are represented, how guidance is provided, and what kind of interface is supported. The findings of this case study reveal that, for 7th graders' problem solving in WELEs, inquiry tools should support structured, yet authentic, tasks.

Peer engagement also influenced participation. Typically, students indicated that they believed it was more productive to work with friends in a group because they learned different perspectives from other group members. At the beginning of this project, the teacher encouraged the students to work together, and the students chose one or two peers to work with. While working in a group was not required, most students collaborated with one or two of their peers. They were each expected to answer WISE questions; however, they worked together to develop a proposal and create their PowerPoint slides.

Facilitator expertise influenced both student problem solving and inquiry tool use. Based on the individual interviews with students and the teacher, the researcher identified six crucial roles that the teacher played in this WELE: teachers as designers, teachers as problem solvers, teachers as context analysts, teachers as coaches, teachers as evaluators, and teachers as community members.

As a designer, the teacher was capable of understanding WISE and modifying projects class use. Also, she was cognizant of students' problem-solving processes, such as how students approach expeditions, and was willing to tackle technical problems that emerged. As a context analyst, she understood students' needs, interests, and capabilities and reflected them in her daily lesson plans. For example, once she realized that the lengthy text in WISE was not useful for her students, she reduced the text for the following class meeting. As a coach, the teacher demonstrated how to use Student Journals when needed and facilitated students' critical thinking using questions, such as "Why do you think this topic is important?" As an evaluator, she pointed out problems she experienced implementing WISE and suggested improvements for the

Ocean Stewards project. As a community member, she willingly shared her experience not only with the researcher, but also with the community of teachers and the WISE team.

Finally, the nature of the curriculum—flexible and student-centered—was also critical. Most participants spoke positively about their experiences in this technology-rich, project-based class, stating that they enjoyed learning new tools and programs based on their needs and interests:

> It's probably the best class we have in school because we get to do with a lot with computers, and in regular computer science class we learn word processing and typing. But here we learned about all new programs in this class. So it helps us a lot to learn all the different stuff. (Paul, post-interview, 3/4/2004).

This learning setting for Case Study 3 was unique in that the students did not take standardized tests and the projects were not restricted to a predetermined curriculum. The salient characteristics of this learning environment include (1) student-centeredness (students select a sub-topic that they want to investigate); (2) students' ownership over their learning pace (about 90% of the class period is assigned to individual or group work, and students are responsible for making progress in their projects); and (3) opportunities to learn new computer tools to create their own artifacts. These characteristics allowed the teacher to select and customize inquiry tools according to students' needs, and it also allowed students to focus on their own meaningful problems.

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CHAPTER 4

SCAFFOLDING 6^{TH} GRADERS' PROBLEM-SOLVING IN WEB-ENHANCED, PROJECT-BASED CLASSROOMS[1]

[1] Kim, M. C., & Hannafin, M. J. To be submitted to a *journal for Instructional Technology audience.*

Introduction

Much research has been conducted to examine the impact and use of computers in the classroom and to facilitate student and teacher activities in technology-enhanced learning environments. Recently, in response to the calls from the National Standards (National Science Education Standards, 1996, 2000), considerable effort has been invested in developing sustainable technology-enhanced science learning environments (Fishman & Krajcik, 2003; Linn, Clark, & Slotta, 2003).

Data published by the National Center for Education Statistics (NCES) document the impact of student-centered applications of technology on student's learning. In a recent national report on science teaching and learning (http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2002452), the National Assessment for Educational Progress (NAEP) reported that 4th grade students whose teachers incorporated computers into their teaching for "playing learning games" had significantly higher science test scores than the students whose teachers did not; among 8th graders, students whose teachers utilized computers for "simulations and models" and "data analysis" in science classes also obtained significantly higher scores than those whose teachers did not. The frequency of science teachers' computer use for data collection and analysis was also positively associated with 12th grade students' science achievement scores. This report provides strong evidence of the impact of student-centered technology integration on science achievement in everyday classrooms.

However, the manner of computer integration and support may improve or hamper student learning. Cuban, Kirkpatrick, and Peck (2001) studied the impact of computers on teaching and learning in two high schools located in the Silicon Valley area in Northern California. Through the observations of classroom practices and interviews with teachers, they reported that computers were used mostly to support traditional didactic teaching methods rather than student-centered classroom activities. Such findings suggest that classroom use of computers and the World Wide Web are widely directed toward lower-order cognitive tasks (e.g., word processing, information finding); in everyday classroom settings, technology is rarely employed to promote critical thinking or higher-order problem-solving. Wallace, Kupperman, Krajcik, & Soloway (2000) documented challenges that 6^{th} graders encountered in their use of the Web-based materials and resources in effectively filtering online resources, selecting and framing evidence, linking it to their conjectures, and developing in-depth scientific understanding. Clearly, both teachers and students need support in order to integrate technology to support higher-order scientific inquiry and reasoning in everyday classroom settings (Anderson & Helms, 2001; Schneider, Krajcik, & Blumenfeld, 2005).

Shin, Jonassen, and McGee (2003) suggested the need to better understand how students solve scientific problems if we are to support inquiry activities that stress both content and process knowledge (Edelson, 2001; NRC, 1996, 2000). Theoretical frameworks grounded in constructivism have been proposed to guide development and implementation of student-centered, technology-supported, problem-solving activities [see, for example, Hannafin, Land, & Oliver (1999) for open-ended learning environments, Kim & Hannafin (2004) for inquiry-supported learning environments, CTGV (1992, 1997) for anchored instruction, project-based learning (Krajcik et al., 1998), and computers as learning partners (Linn & Hsi, 2000)]. In contrast to traditional instructional design approaches (Gagne & Briggs, 1974), contemporary inquiry frameworks emphasize reconstruction of knowledge and beliefs (von Glasersfeld, 1989, 1993), authentic learning experience (Herrington, Reeves, Oliver, & Woo, 2004), teacher roles as facilitator and knowledge co-constructors (Crawford, 2000), and technology roles as cognitive tools (Jonassen & Reeves, 1996).

In inquiry-oriented science classrooms (NRC, 1996; 2000), problem-solving activities typically involve students finding or generating scientific problems that reflect scientific phenomena and enable students to investigate in class, posing their own hypothesis or positions, utilizing technologies and tools to explore the problems, and generating and justifying their conclusions (NRC, 1996; Kim & Hannafin, 2004). For the purpose of this study, problem-solving is defined as deliberate activities where students pose, investigate, and solve meaningful scientific problems by inquiring through five iterative and interactive phases: problem-identification, exploration, reconstruction, presentation and communication, and reflection and negotiation.

While interest in student-centered learning environments has grown, little is known as to how students solve problems using technology in everyday classroom settings. The potential of technologies to scaffold inquiry tasks has been examined extensively (e.g., Quintana et al., 2004; Reiser, 2004; Tabak, 2004). Computer-based technologies enable students to access resources (Hill & Hannafin, 2001), to visualize their thinking (Edelson, Gordin, & Pea, 1999), to model scientific phenomena by manipulating variables (Barab, Hay, Barnett, & Keating, 2000; Jackson, Krajcik, & Soloway, 2000), and to utilize structured web-based activities through experiencing inquiry processes (Linn, Clark, & Slotta, 2003). For example, the Web-based Science Environment (WISE) was developed to promote students' knowledge integration in science education by providing a web-based problem-context where students can find and resolve problems. Working with this environments, students are assisted to make connections between their prior knowledge and the current problem context utilizing guided activities, visualization and modeling tools, web-based resources as evidence, and communication features embedded (Linn, Clark, & Slotta, 2003).

However, research has provide little insight into the cognitive and social strategies used during classroom-based inquiry or the roles of different scaffolds—human as well as technological—during student problem-solving. Research on scientific inquiry has consistently identified student difficulties utilizing technologies and the Web during problem-solving due to factors such as limited prior knowledge and experience, cognitive overload, inability to monitor their inquiry processes, and lack of experience in evaluating their naïve theories and beliefs using evidence (Edelson, Gordin, & Pea, 1999). These challenges are compounded by contextual influences such as teacher role (Windschitl, 2005; Windschitl & Sahl, 2002), peer support (Ge & Land, 2003; Scardamalia & Bereiter, 1991), and culture of school communities (Songer, Lee, & McDonald, 2003). Little is known how these diverse factors influence students' scientific problem-solving and inquiry processes in everyday school settings.

The purpose of this study was to examine how students solve scientific problems in Web-enhanced learning environments (WELEs). The following questions guided the study:

1. How do middle school students identify, explore, and solve scientific problems in a Web-enhanced learning environment?
2. How do they use different types of scaffolding (peer, teacher, and technology-enhanced) during their problem solving, inquiry processes?
3. What factors influence middle school students' inquiry in the Web-enhanced learning environment?

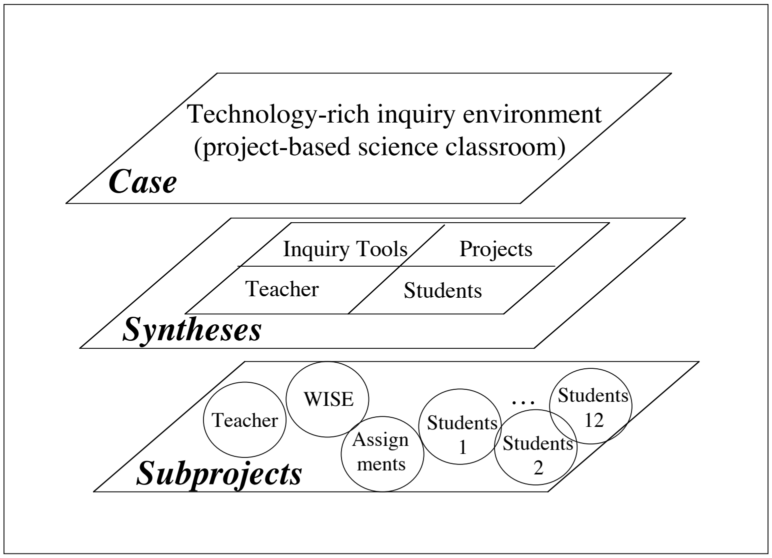
Methods

Research Design

The purpose of this descriptive case study (Yin, 2003) was to examine middle school students' in-class knowledge construction, problem-solving, and meaning-making processes during Web-Enhanced, inquiry-based learning. This study was designed to provide rich descriptions of an instrumental case study exploring students' problem-solving processes in a particular case, rather than to evaluate the WELE itself. Accordingly, this study was aimed at understanding complicated processes, describing students' problem-solving processes with computer tools, and providing contextual description (Marshall & Rossman, 1995). The case is a bounded, integrated system (Stake, 1995) (Web-Enhanced Learning Environment) that, because of its unique curriculum and infrastructure, yields rich and in-depth descriptions (Merriam, 2002).

In order to conceptualize the architecture of the case, to incorporate the nested cases (individual students, teacher, inquiry tools, and students' projects) under the umbrella case (the WELE), and to examine a multifaceted, contextualized research problem, an embedded case study method was used. Figure 4.1 depicts the conceptualization of the embedded cases in this study. Scholz and Tietje's (2002) three levels of knowledge integration are shown as embedded case studies: understanding the case (first level—one overall case), conceptualizing syntheses (second level—the system of the first level), and explaining subprojects (third level—individual subject to investigate and to collect data from).

Figure 4.1. Architecture of knowledge integration in embedded case studies (Modified from Scholz & Tietje, 2002)



Research Context and Participants

The technology-rich, project-based 6th grade course was offered in a middle school in a suburban area of the Southeastern United States. Two classes were selected for the study. As an elective course for gifted students, these classes were designed to help students experience project-based research using advanced computer skills. For instance, the students worked on 3-week projects, such as creating movies using iMovie and Macromedia Flash, and they each had access to a computer. The course was recognized for its innovative curriculum, where teachers integrate technologies in constructive ways, and for its popularity among students who report doing “cool stuff” (interview, 11/21). The course had been offered by the same instructor for three previous years to help students do technology-enhanced individual and collaborative research on science and social studies topics. Beginning in the Fall of 2004, the middle school was split into two schools due to the growing number of students; 50% of the teachers and students in that school were moved to a new building in the same school district. The classroom teacher with whom the researcher collaborated also moved to the new school, but the goal and activities of the classes were unchanged.

The course was selected because of its focus on student-centered learning. The goal of the course was to provide students with unique opportunities to build “research” skills with a variety of topics and to help students use technologies as a major resource for their own investigations. The teacher rarely lectured on procedures that students needed to follow; rather, she provided individual scaffolding when questions arose. While working with the classroom teacher and students in the preliminary studies, the researcher noted that the students spent most of their time discussing and refining ideas with their peers and learning to represent their progress and outcomes through tools such as Microsoft PowerPoint, Apple Keynote, Macromedia Dreamweaver, and Macromedia Flash.

Finally, the course was selected because of its flexibility in allowing the implementation of new technologies and curricula. During previous interviews with the teacher, the researcher found that she believed learning involves constructing knowledge through the learners' experiences and was receptive to innovative ways to integrate technologies into her classroom. The preliminary studies also revealed that the classroom environment provided both students and teacher with a great deal of flexibility.

Class A comprised a teacher (a former scientist) and 16 students (10 boys and 6 girls). Class B consisted of the same teacher and 28 students (15 boys and 12 girls). The students represented diverse ethnicities such as European American, African American, and Asian American, but European Americans were predominant. The researcher purposely selected students to maximize the variations among them based upon three criteria: (1) gender—

participants represented both male and female students because research shows substantial gender differences in scientific topics, communication skills, and ways of constructing scientific knowledge (Adamson, Foster, Roark, & Reed, 1998; Mattern & Schau, 2002; Rodriguez, 1997); (2) level of interest in technology and subject matter; and (3) level of collaboration—participants included students who actively shared ideas with both group and non-group partners. The student survey (Appendix B) was used to identify the level of student interest, to better understand both problem solving and subject matter, and to guide the researcher's observations of group collaboration patterns.

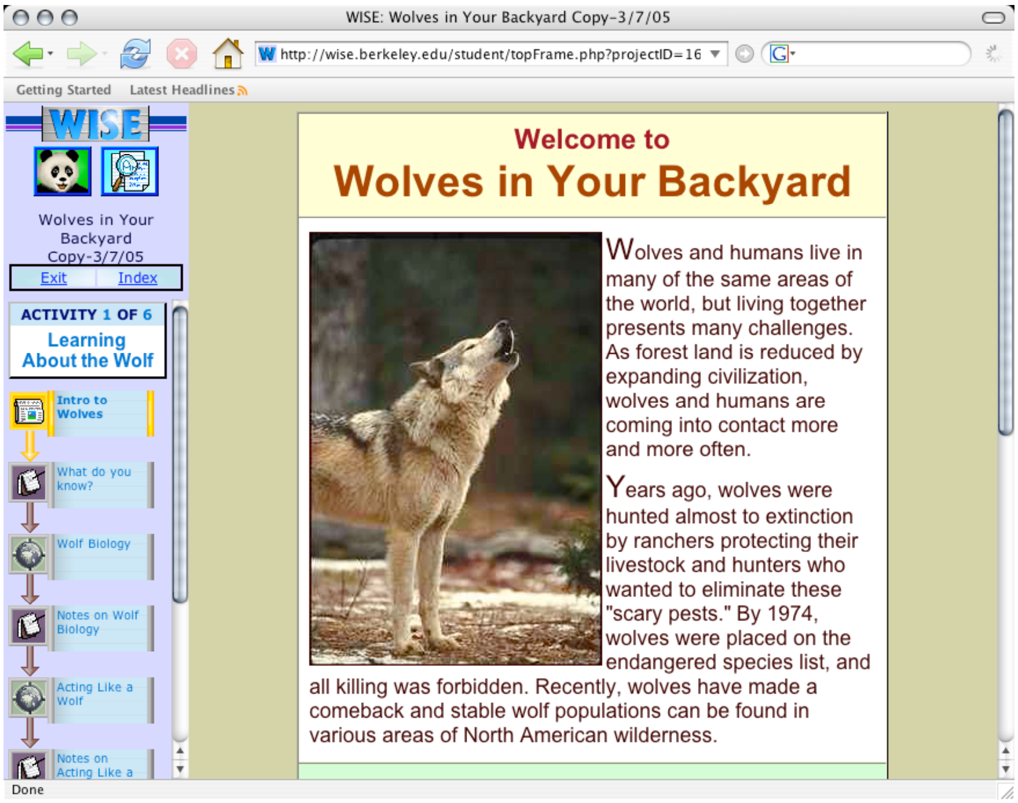
Research Materials

WISE (Web-based Inquiry Science Environments). As an expanded version of Knowledge Integration Environment (Bell & Linn, 2000), the *Web-based Inquiry Science Environments (WISE)* project was developed to bridge both the gap between students' naïve scientific assumptions and their learning practices and the gap between the project-based innovations used by researchers and the classroom practices used by teachers (Linn, Clark, & Slotta, 2003). The researchers focused on creating and supporting school-based technological reforms for science learning in collaboration with scientists, teachers, curriculum designers, and technologists (Linn & Slotta, 2000). To help students apply learning activities to their existing knowledge bases and daily experiences, Linn (2000) proposed the four design strategies upon which WISE was developed: (a) make science accessible by encompassing scientific models, visualizations, and cognitive and procedural scaffolds; (b) make thinking visible by supporting tools for multiple representations and interactive visualizations; (c) help students learn from one another by incorporating web-based discussion boards, debatable issues, and assignments for peer reviews; and (d) foster lifelong learning by presenting controversial scientific issues that are relevant to students' daily experiences. The WISE library contains 25 projects covering diverse categories for scientific investigation, controversy, critique, and design, and various topics for biology, chemistry, earth science, environmental science, physics, and more (Linn, Clark, & Slotta, 2003).

In this study, WISE provided a Web-based meta-context where students identified, explored, and reconstructed authentic scientific problems in the classroom (Figure 4.2). WISE was selected due to its long history of development, continuous refinement based on research findings, collaborative design by scientists, practitioners, students, engineers, and researchers, and its flexibility and scalability for implementation in local classrooms.

Figure 4.2. WISE (Web-based Inquiry Science Environment) Intro Page

Figure 4.3. Selected Project—*Wolves in Your Backyard*



Based on a discussion with the classroom teacher and local technology coordinator, one project from the WISE library, "*Wolves in Your Backyard*" (Figure 4.3), was selected to implement based upon these criteria. First, the project provided authentic problems or problem contexts for potential participants, which allowed participants to identify and explore issues related to their own experiences. For example, in the project, students were introduced to the following problem context related to their own lives:

> If we continue to offer wolves complete protection, their numbers may bloom until they are seen as a problem again. So... full protection could actually backfire since it would give wolves a bad name! But if we remove all protection, then wolf killing will resume. This would wind up reducing their numbers until we were right back where we started!

> Should we offer limited protection, allowing ranchers to kill wolves who come near their farms? What should we do if wolves kill a child who is camping in the forest with family or friends? These are difficult questions, and scientists do not always agree about their solution. It is important to think about whether the environment needs predators like the wolf. How many wolves can the shrinking wilderness really support?
>
> Obviously, the future of these animals depends on scientists, politicians, and private citizens to make the right decisions. In this project, you will examine some of the arguments from various perspectives. You will even think about your own solution to the problem!

Second, the Wolves project supported different inquiry activities for scientific investigation. For example, participants made a virtual observation of scientific phenomena, examined different positions and alternatives, found evidence that supports or refutes the positions, and linked their own positions to the evidence (National Research Council, 1996). Using these supports and WISE as a meta-context for problem solving, students reconstructed and solved problems.

Third, the project technologically and pedagogically supported diverse types of scaffolding (peer, teacher, and technology-enhanced). For instance, the project was incorporated into an open-ended problem (i.e., creating a brochure), and in the process of working with problems, students received assistance from their partners, teacher, and WISE itself. In the selected WISE project, students read teachers' comments and other students' ideas and shared their own thoughts with other people in the classroom.

Technology-enhanced scaffolding (pedagogical support) from WISE. In this study, three major features of WISE were identified for the participants to use in situated problem solving: guided inquiry, electronic notes, and hints. Students' investigations of problems were scaffolded by guided inquiry, which is called “Activities” in the WISE project. Although students found open-ended problems at the beginning of the investigation (typically in the first step of Activity), they used structured phases to reconstruct and solve the problems. The phases included, for instance, finding evidence, presenting their positions, and communicating with other people. Students visually monitored the phases of their activities by looking at the left menu of the project (Figure 4.4), clicking on the “Index” (Figure 4.5), and checking their work linked to the magnifying glasses (Figure 4.6).

Figure 4.4. Sample guided inquiry supported by WISE

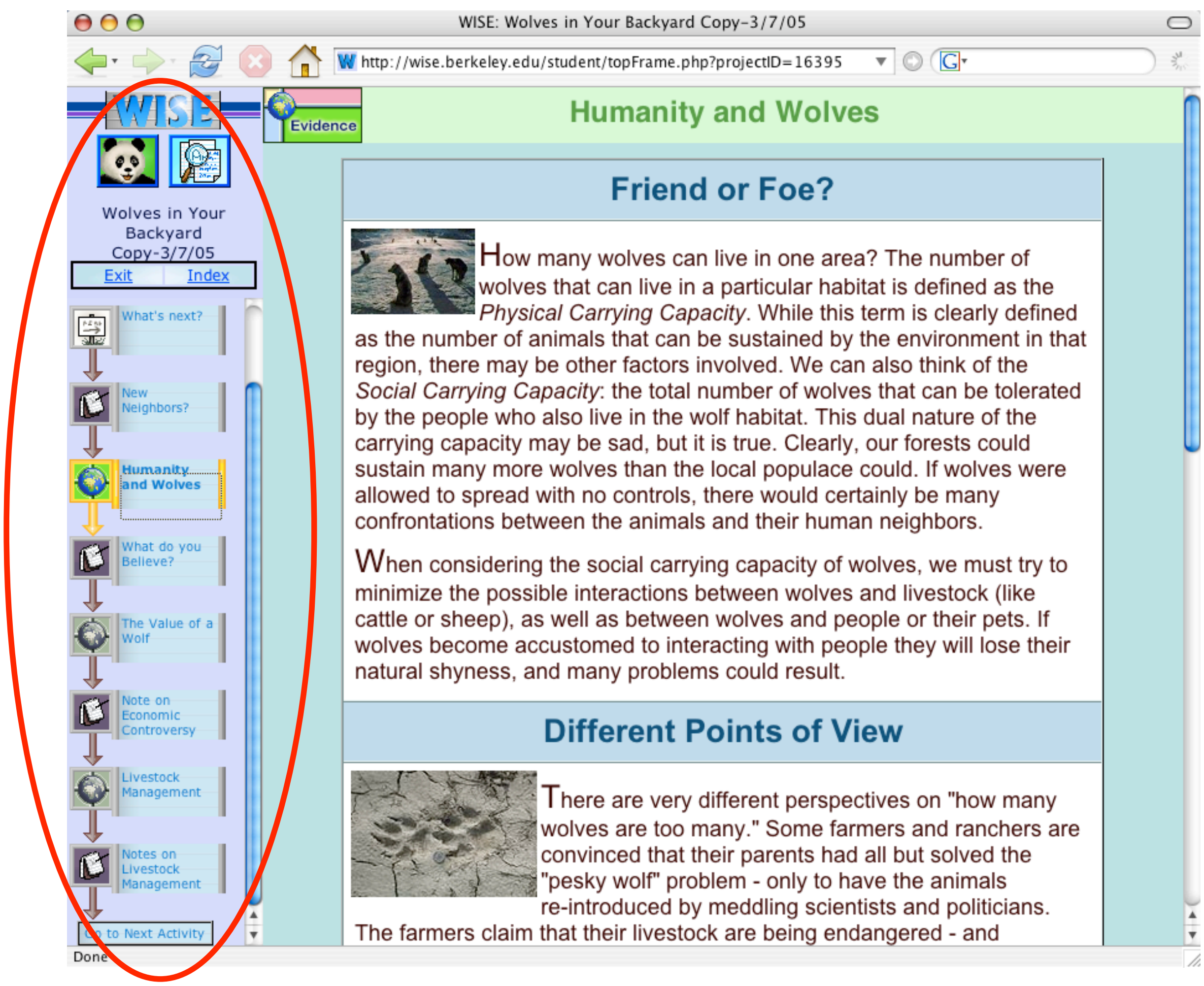


Figure 4.5. Index of WISE Activities

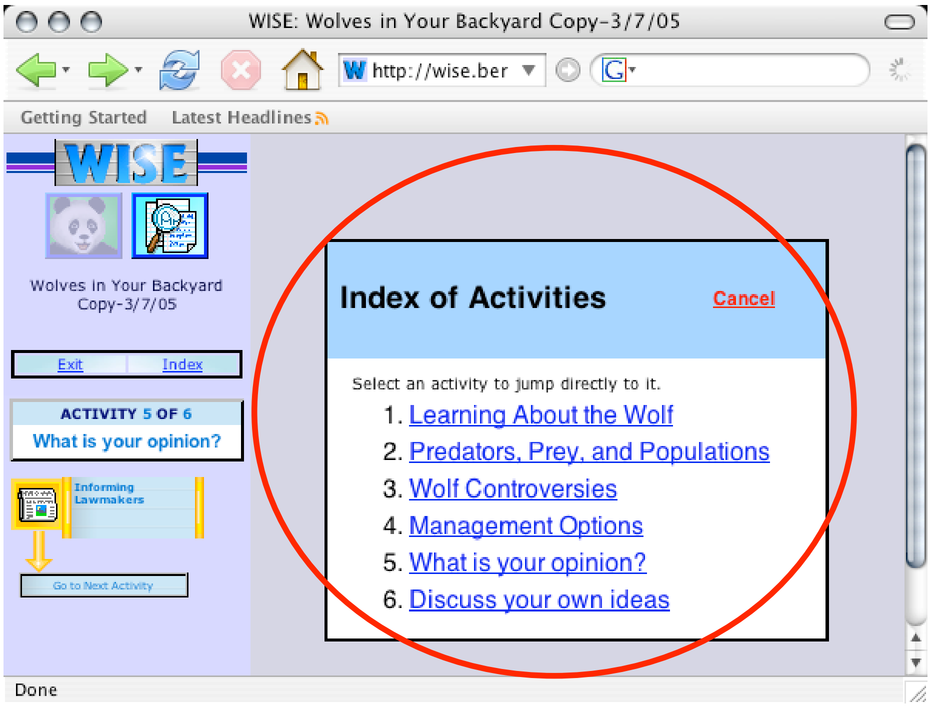
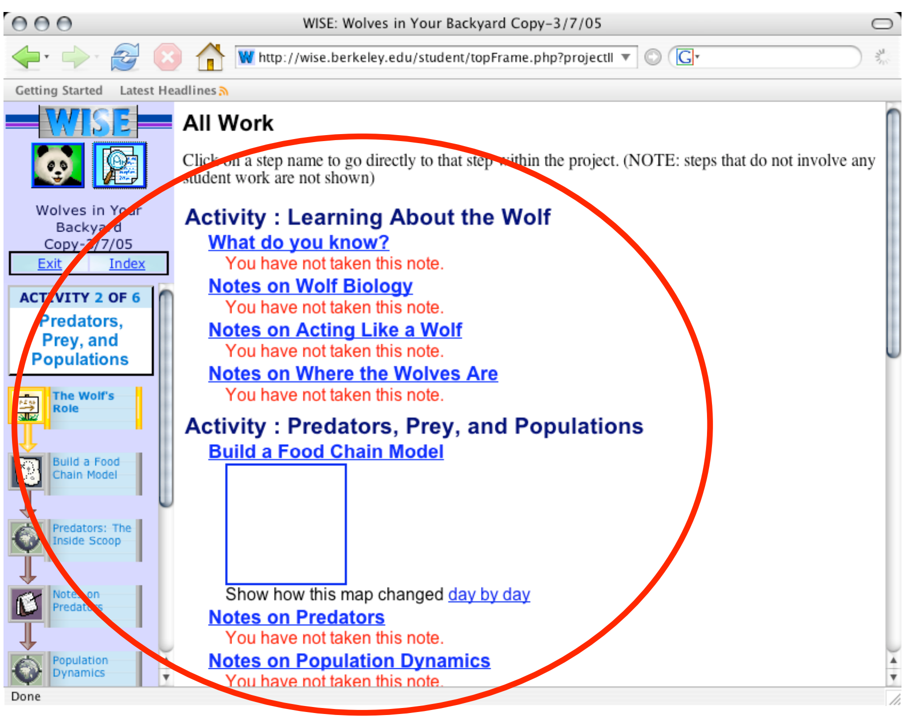
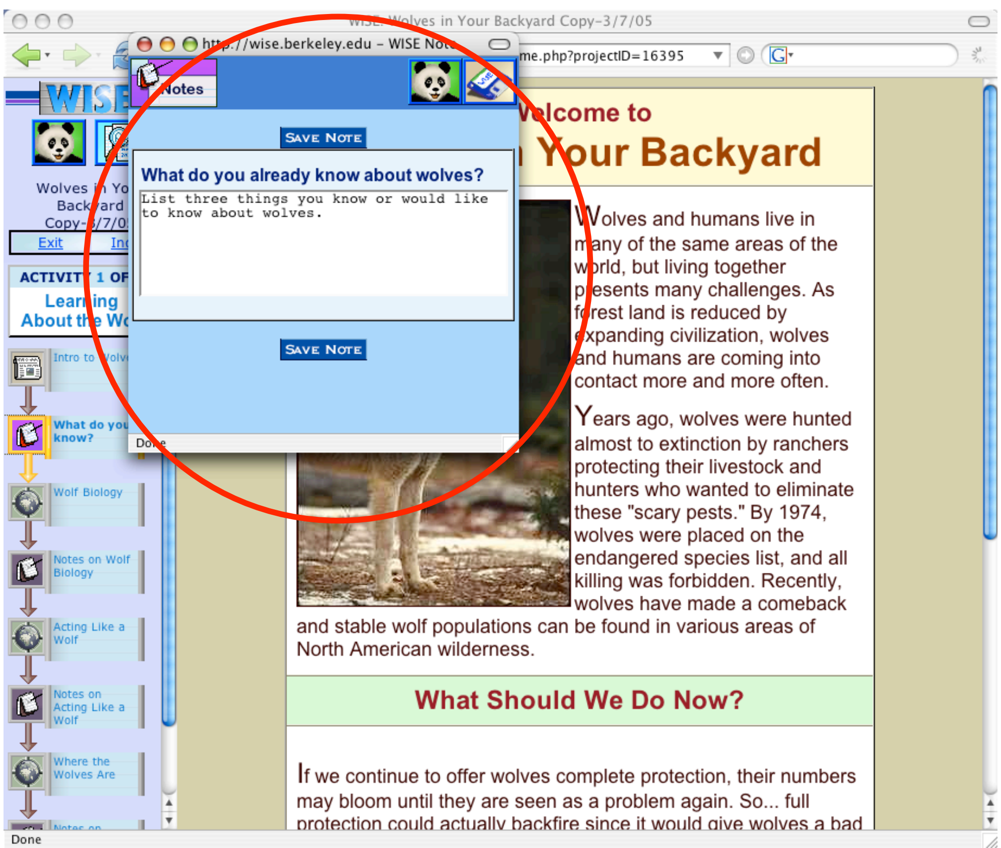


Figure 4.6. Students' Work in WISE



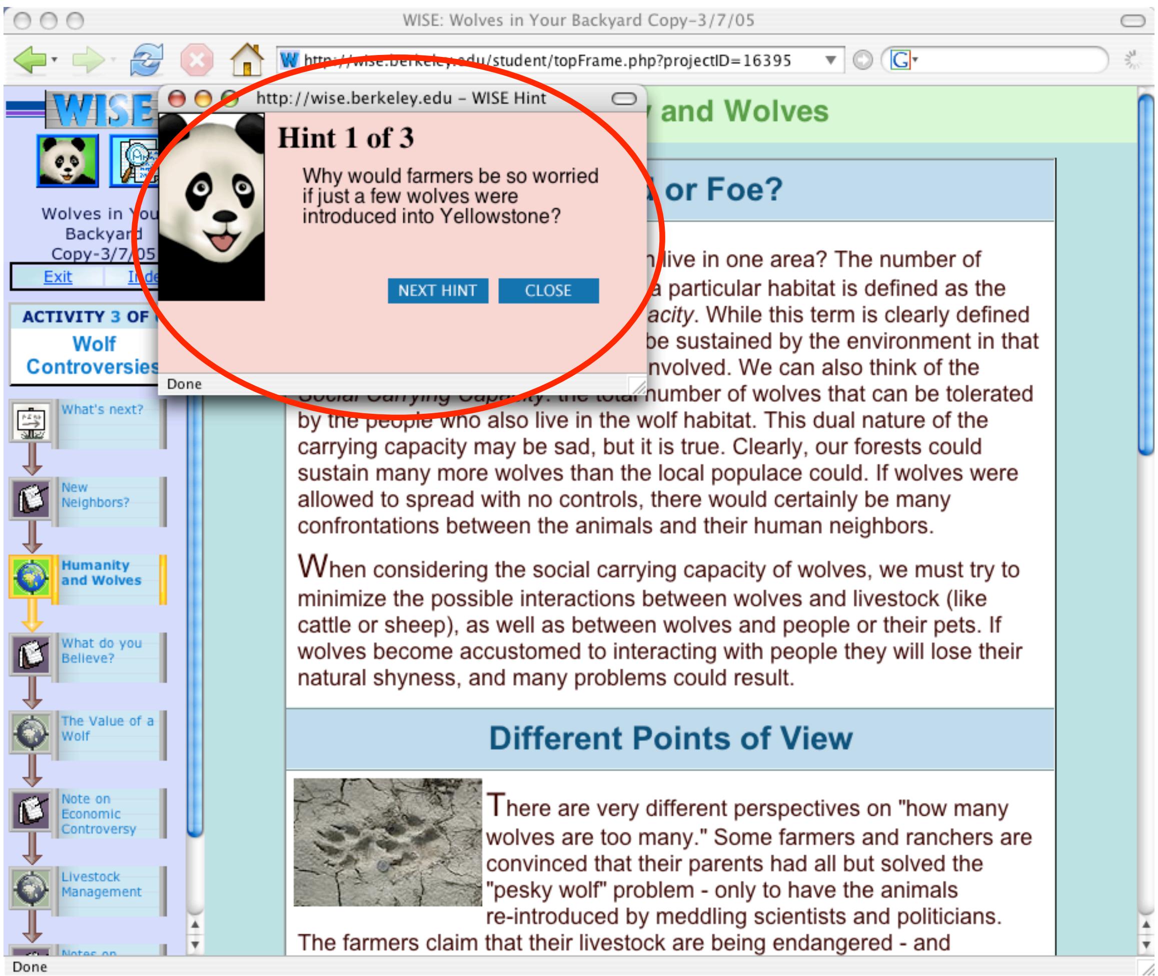
Electronic notes embedded in WISE were also designed to support scientific investigation. Preliminary studies indicated that most students experienced difficulty developing problem-solving and higher-order thinking in open-ended problem contexts. However, the studies also indicated that the indexed activities and writing features (notes and journals) for students' reflection facilitated their inquiry by providing metacognitive and procedural assistance. As shown in Figure 4.7, WISE Notes helped students to reflect on their thinking after examining evidence presented in the project. Typically, the Notes included questions such as "What do you think about this problem?", "Why do you think so?", and "Why (or why not) do you think the evidence is credible?"

Figure 4.7. WISE Notes



Finally, students used the Hint option to answer the questions posed in WISE Notes (Figure 4.8) by selecting the "Panda" icon in the Notes window. Typically, the Hint reframed the questions or represented different perspectives on them.

Figure 4.8. WISE Hint

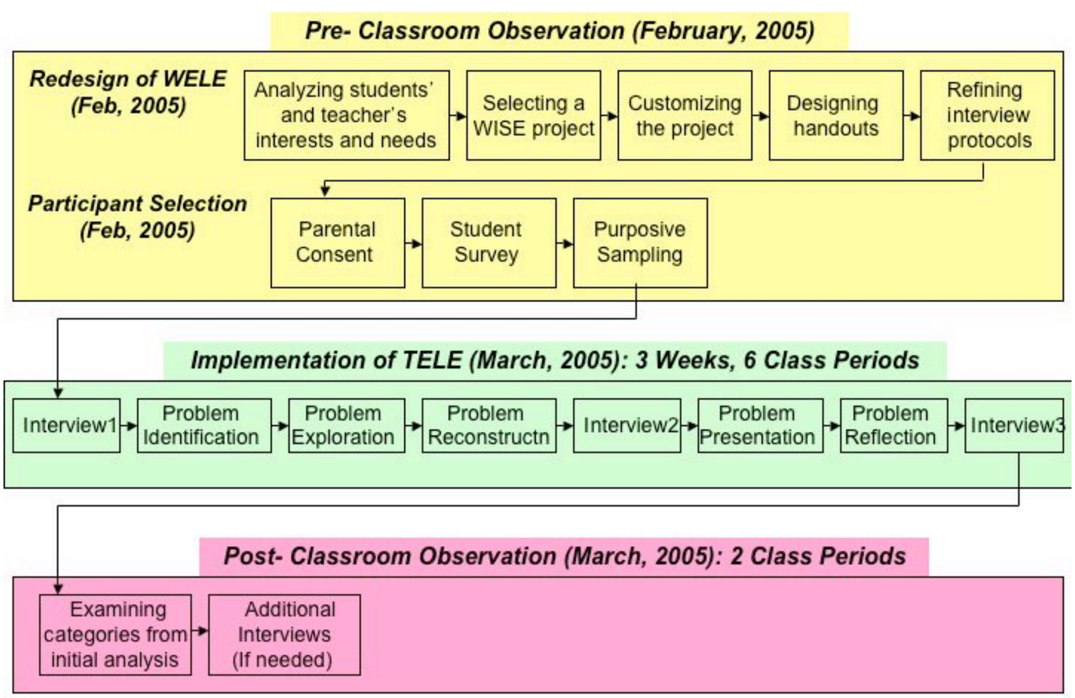


Based on WISE pedagogical supports, project goals and scoring rubrics were provided to help students understand the requirements of the online brochure and essential questions they needed to consider during the design of the brochure (see Appendix B for Project Handouts and Scoring Rubrics).

Data Collection Procedures

The primary researcher and classroom teacher collaborated to design and implement the WELE in the Spring of 2005, and the researcher collected data from multiple sources in the same period. This study employed three substantive phases: pre-observation, implementation, and post-observation. Figure 4.9 portrays an overview of the three phases with major tasks relevant to each.

Figure 4.9. Overview of research procedures



<u>*Pre- classroom observation.*</u> During this phase, the researcher and the classroom teacher collaborated to select and customize one WISE project and design necessary instructional

materials (e.g., handouts) based on the goal of the project and this research. During the first week of this phase, the researcher brainstormed and discussed ideas related to selecting a WISE project from the library that was appropriate to students' interests and their needs. They also examined what they learned from the WISE projects they had used in the previous studies (e.g., *Genetically Modified Foods, Ocean Stewards*). The pre-determined criteria for the project selection, described in Materials, guided this task. After spending approximately one week carefully investigating the pros and cons of potential projects for the classes, they finally chose a project, *Wolves in Your Backyard*.

Next, the researcher and the classroom teacher customized the project based on the limitations they found from the previous WISE implementations. Rather than thoroughly probing into evidence and problems in each Activity, many students quickly jumped into the Discussion part of the projects, where they used chat rooms and exchanged superficial ideas and casual conversations. The teacher and the researcher decided to design an open-ended and authentic task—the creation of an online brochure to inform local policy-makers and tourists of the best wolf management plan. They added two more Web pages to the existing project in the WISE database (Figures 4.10 and 4.11) and designed the guidelines for the brochure design (Appendix B).

Figure 4.10. Customized Project Activity (Activity 5. What Is Your Opinion?)

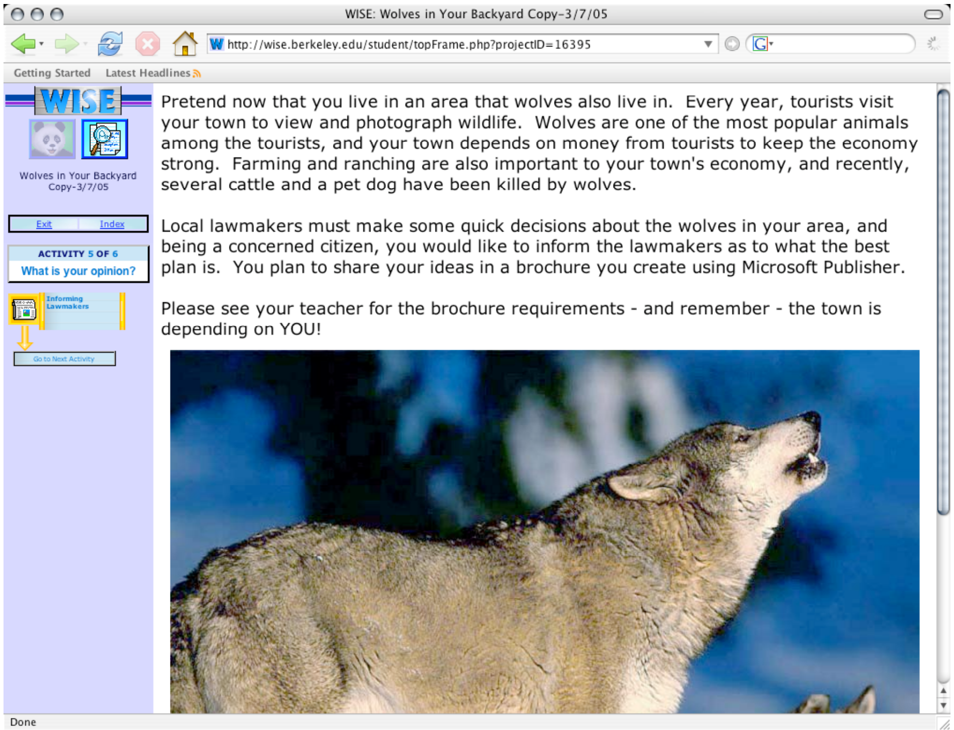
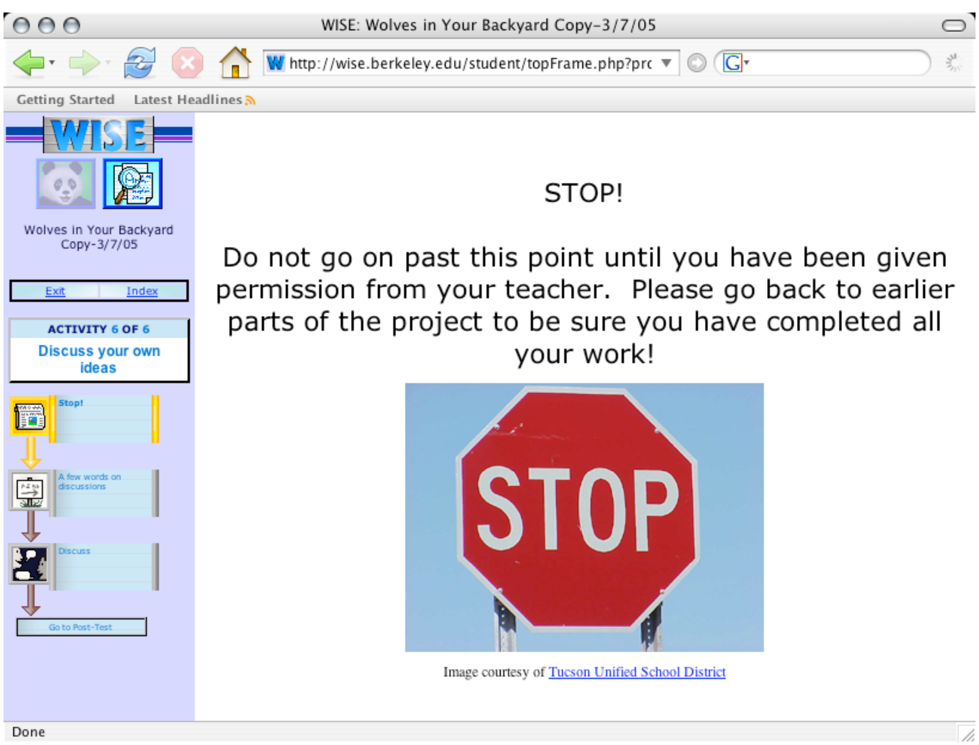


Figure 4.11. Customized Project Activity (Activity 6. Discuss Your Own Ideas)



Next, they developed instructional materials for students based on the goals of the projects, which guided students' collaborative problem solving and guided inquiry. Since students worked on the open-ended task, it was essential to design and provide hands-on materials to reduce their cognitive overload and to expedite their understanding of procedural skills, such as how to register in WISE and where to get help finding more evidence. Based on the selected project and redesigned curriculum, the researcher refined the initial list of interview questions for the three subsequent semi-structured participant interviews (see Appendix C for interview protocols).

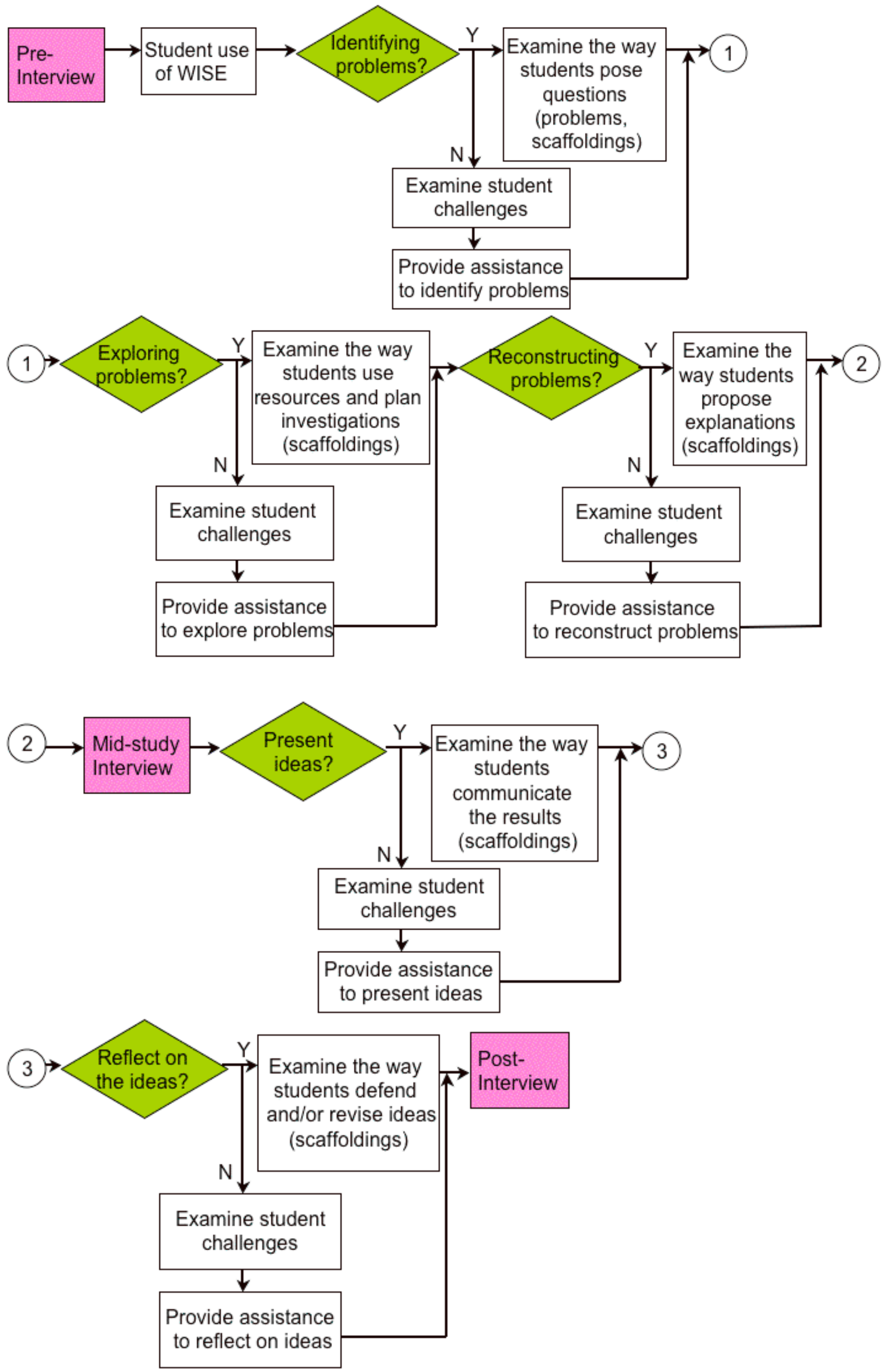
On receiving parental consent from potential participants, the researcher encouraged students to complete the survey (Appendix B). Based on the results from the survey and the three criteria presented in Context and Participants, the researcher recruited a total of 19 students: 1 African American female and 18 European Americans (10 female, 8 male). Nineteen students were selected from each of two sections (10 and 9 respectively) to ensure maximum variation sampling (Glaser & Strauss, 1967). Ten students reported "Very High" interest in technology; one reported "Low" interest in technology. Self-reported interest in science and subject matter ranged from "Very Low" to "Very High."

WELE implementation. During this phase, the classroom teacher and the researcher facilitated students' classroom activities with the selected WISE project and discussion with peers. The teacher actively monitored students' progress and provided formative feedback on each phase of problem solving using the electronic message, individual comments, and face-to-face assistance. As a participant-observer, the researcher focused on capturing a "big picture" of the classroom and uncovering the dynamics of students' knowledge-construction processes. The researcher frequently asked students questions for clarification in an informal and timely manner.

Elaborated procedures for the implementation phase are depicted in Figure 4.12. Consistent with the presented conceptual framework, the WELE implementation consisted of five substantive sub-phases: problem identification, problem exploration, problem reconstruction, problem presentation, and problem reflection. In each phase of problem solving, the teacher and researcher monitored students' cognitive and social processes of knowledge building and diagnosed the challenges and issues that students faced in each phase. The researcher examined the different types of strategies and scaffoldings that they utilized. Individual interviews were conducted at least three times per participant: before the project activity, during the activity, and after the activity. Interview protocols and detailed descriptions regarding the purpose of each interview are depicted in Appendix C.

Post- classroom observation. During this phase, the researcher examined the tentative findings from the initial analysis and asked the participants and the teacher more questions for clarification and triangulation.

Figure 4.12. Overview of implementation procedures for WELE



Data Sources

A wide range of data from multiple sources was collected (a) to yield rich descriptions of students' knowledge-construction processes and the strategies they used to solve problems in the WELE, and (b) to triangulate the data analysis processes from multiple perspectives. Data sources included individual interviews with the participants as the major source of data, participants' electronic notes saved in the WISE database, online brochures created by the students, the researcher's field notes generated from daily observations, and videotapes of students' group activities. Table 4.1 represents the different types of data collected in accordance with the research phases, and Table 4.2 aligns the multiple data sources to the research questions.

Observations and field notes. During the six-class-period activity, the researcher made extensive observations in the two classes. Prior to collecting data from the three-week activity, the researcher had prior understanding about the classes and potential participants because she began her observations at the beginning of the Spring semester of 2005. Field notes from these observations were recorded each time the researcher visited the classes using the format shown in Appendix D.

Table 4.1. Multiple data sources in each phase of study

Research plan	Period	Data Sources					
		Field notes	Interview	Student notes	Brochure	Survey	Videotapes
I. Pre-Classroom Observation	***Feb. 2005***						
1. Redesign of WELE							
Selecting a WISE project	2nd week	***					
Customizing the project	3rd week	***					
Designing handouts	4th week	***					
Refining interview questions	4th week	***					
2. Participant selection	***Feb. 2005***						
Parental consent		***					
Student Survey		***				**	
Selecting participants		***					
II. Implementation of WELE	***Mar. 2005***						
Pre-interview		***	***				
Problem identification		***		**			*
Problem exploration		***		**			*
Problem reconstruction		***		**	**		*
Mid-study interview		***	***				
Problem presentation		***		**	**		*
Problem reflection		***		**	**		*
Post-interview		***	***				
III. Post-Classroom Observation	***Mar. 2005***						
Post-interview		***	***				

Table 4.2. Alignment of multiple data sources to research questions

Research questions	Field notes	Interview	Student Notes & Journal	Brochure	Survey	Videotapes
1. How do middle school students identify, explore, and solve scientific problems in a Web-enhanced learning environment?	***	***	**	**	**	*
2. How do they use different types of scaffolding (peer, teacher, and technology-enhanced) during their problem solving, inquiry processes?	***	***	**	**	**	*
3. What factors influence middle school students' inquiry in the Web-enhanced learning environment?	***	***	**	**	**	*

*** Major sources of data
** Secondary sources of data
* Supplementary sources of data

<u>Interviews.</u> Individual interviews of approximately fifteen to twenty minutes in length were conducted twice, on the first and the last days of the project (pre- and post-interviews), and approximately three- to five-minute individual interviews were conducted during the project activities (mid-study interviews). The first semi-structured interview focused on participants' prior knowledge and experiences with the selected scientific topic, general beliefs about scientific investigation and the nature of science, and perceptions about using technologies in their learning. The second semi-structured interview focused on the strategies that students had used and the challenges they had faced in the processes of problem identification, exploration, and reconstruction. Also, the researcher asked participants if or how their perceptions had changed regarding the selected scientific topic, way of investigating scientific problems, and their uses of technologies. The third semi-structured interview was conducted to examine students' challenges and strategies in the processes of problem presentation and reflection. In addition, participants were asked to describe their overall reactions to the WELE and any changes in their perceptions. All the interviews were audiotaped and transcribed. Interview protocols for the three interviews are specified in Appendix C.

Documents. Students' electronic WISE notes and journals were used as secondary sources of data. From the previous studies, the researcher found that students were able to use WISE notes and journals to further their thinking and to monitor their learning processes. For example, by answering the question "Why did you select this particular expedition?" in the WISE journals, the students had a chance to reflect on their own interests and the importance of the selected topic. In addition, those data sources were helpful to the researcher in uncovering participants' thinking processes.

Videotapes. Students' group activities were recorded on videotape. Since the researcher was unable to capture all of the discussions and activities during class, the videotapes helped the researcher explore group-based inquiry activities and think-aloud thinking processes as a supplemental source of data.

Students' brochures and surveys. These data were used as supplementary sources. The student survey helped the researcher to select participants from the classes using the three criteria, and the students' brochures assisted the researcher in triangulating the multiple data sources by examining whether there was any mismatch among the different sources of data.

Data Analysis

Hannafin and Land's (1997) foundations of student-centered learning environments (psychological, pedagogical, technological, cultural, and pragmatic foundations) guided the collection and analysis of data regarding the second research question. Research on problem-solving in everyday technology-enhanced learning environments requires a practical, interactive, and iterative design perspective. In addition, preliminary studies suggested that the need for a comprehensive framework to categorize WELE design activities in order to examine the interdependence among design factors.

Procedures. Data were collected from multiple sources (transcripts of interviews and student discourse from audiotapes, WISE notes and journals, field notes, brochures, and surveys) and analyzed to find critical, consistent themes in qualitative ways. Based upon the analysis strategies to build a substantive theory, data were analyzed using constant comparative data analysis (Glaser & Strauss, 1967). The specific procedures for data analysis included: (1) coding all the data collected from one interview using "inspection and memo-writing" (p. 103); (2) revising the written codes by examining the field notes and documents generated by participants for triangulation; (3) generating tentative categories and sub-categories based on the revised codes; (4) repeating the same procedures from the first three steps for the second interview, the third interview, and the rest of the interview transcripts to examine conflicts and congruence of the data; and (5) finalizing the categories and sub-categories by renaming or relocating them. Regarding each research question, emergent categories and sub-categories were inductively derived and are represented using within-case displays (Miles & Huberman, 1994). A conceptually clustered matrix and a thematic conceptual matrix had been selected among a variety of representational modes (Miles & Huberman, 1994) because the first research question examined different student groups' problem-solving processes as nested cases, whereas the second question focused on the problems and issues in students' inquiry activities.

Validity and Reliability

To ensure internal validity—whether the findings were congruent with what really happened in the case—the researcher used several strategies, including (a) multiple sources of data for triangulation, (b) the researcher's long-term observations, (c) the classroom teacher's participation in the research process, and (d) clarification of researchers' biases. Data were collected from interviews with students and the classroom teacher, from field notes, and from artifacts (e.g., students' electronic notes and PowerPoint slides), and analysis of the data was triangulated by the researcher's examination of the various sources of data. Also, the researcher conducted two preliminary studies in the Spring of 2004 and the Fall of 2003 in the same course prior to this case study and made daily observations during the 3-week activity. In addition, the teacher actively participated and communicated with the researcher in each phase of study.

Regarding reliability (i.e., dependability, consistency), this study sought to make the findings consistent with the data rather than seeking to replicate the results in other contexts. To ensure this, the researcher's assumptions were described prior to data collection (LeCompte & Preissle, 1993) and multiple sources of data were triangulated (Merriam, 1998). To ensure naturalistic generalization (Stake, 1995) and reader generalizabilty (Merriam, 1998; Walker, 1980), the findings were reported with descriptive, vivid data to support each category.

Researcher Statement

I believe that knowledge is socially constructed and not absolute truth, and I doubt that truth will be attained by advances in science and technology. Influenced by Vygotsky (1978) and Lave and Wenger's (1991) work, I consider learning to be a social process involving an individual's developing expertise in a community of practice. I consider myself to be a constructivist who (1) values individually different learning processes and opportunities for conceptual change; (2) focuses on the roles of collaboration, communication, and tools in learning; (3) understands that learning difficulties are often due to the lack of previous experience or motivation; and (4) enjoys applying new technologies to improve current classroom environments. These perspectives have influenced my interviews with the students and the teacher, as well as my interpretations of the data collected from multiple sources, by focusing on incidents related to personal learning and teaching beliefs.

As a strong advocate of technology, I believe that technologies can help people learn what and when they want to learn, in both formal and informal settings, in effective and efficient ways. I view a primary purpose of education as being to help individuals develop problem-solving skills that can be transferred to everyday situations.

Concerning the research problems, I believe every middle school student is capable of finding and resolving scientific problems if adequate assistance is provided. Technologies can provide scaffolds to bridge the gap between what students can do alone and what they can do with assistance. I am very interested in engaging in adolescents' discourse because I believe adolescence is a critical period in life to think deeply about one's future. As a doctoral student in instructional technology, I believe in the potential of using computers and the Internet as cognitive tools in K-12 settings.

Although English is not my first language, after spending four years in the United States, I do not have significant problems communicating with people in English. As an Asian student who grew up in a different culture and who has been taught in different school settings, I spent the past five years volunteering in elementary and middle schools as a tutor, translator, and researcher in order to enhance my practical knowledge in K-12 classroom settings in the United States. Research techniques such as audio-taping the interviews helped me recursively reflect on the critical moments and my interpretations of them.

Findings

Participant Profiles

Profiles for the 19 student participants and work groups are summarized in Table 4.3. The unit of analysis in this study was the individual student. However, while students within the same group often demonstrated similar problem-solving patterns, variability was observed across the groups. In the preliminary studies, we identified five problem-solving patterns among 7th graders: inquirers, reasoners, negotiators, trial-and-error students, and right-answer students (Kim & Hannafin, 2005). In this study, we noted variations in each pattern, and expanded the classification: Quiet inquirer group, communicative inquirer group, self-contained reasoner group, peer-supporting reasoner group, steady negotiator group, prompt negotiator group, and unfocused trial and error group students.

Quiet Inquirers. In the preliminary studies, inquirers already had (or developed) interest in project subject matter, recognized the importance of discussion topics, examined evidence and different perspectives, and re-constructed their own position (Kim & Hannafin, 2005). In the current study, Quiet Inquirers focused on their own project (i.e., management of wolf populations) and rarely engaged in discussion with peers. Jamie, for example, indicated the most interest in the subject matter (wolves) in the two classes; according to the teacher's assessment, she works diligently and submits the "best" work she can do. Jamie expressed her interest during the pre-interview: "When I grow up, I think I want to do something that has to do with wolves or computers. Because I love wolves. Whenever I can I read about wolves or books or fiction or nonfiction" (pre-interview, 3/3). Her partner, Leslie, expressed her positive attitude toward the subject matter: "Science is fun, but it's once of my more difficult subjects, but I still try my hardest and its' really fun, too" (pre-interview, 3/1).

Table 4.3. Participant Profiles

Class	Name	Gender	Group Characterization (# of members[1])	Level of interest (self-report)		
				Technology	Science	Subject Matter (wolves)
6A	Leslie	Female	Quiet Inquirer (3)	Very High	High	Average
	Jamie	Female		Very High	Very High	Very High
	Natalie	Female		Average	High	Average
	Ethan	Male	Self-contained Reasoner (2)	Very High	High	Average
	Justin	Male		Average	Low	Low
	Sydney	Female	Prompt Negotiator (3)	High	Average	Average
	Ashley	Female		Very High	High	Average
	Steven	Male	Unfocused Trial-and-error Students (3)	Very High	Average	Very Low
	Kevin	Male		Very High	Very High	Average
	Anthony	Male	Prompt Negotiator (3)	High	High	Very Low
6B	Paige	Female	Communicative Inquirer (2)	High	High	Average
	Jade	Female		High	High	Average
	Jen	Female	Peer-supporting Reasoner (2)	Very High	Very Low	High
	Allison	Female		Low	Low	High
	Timothy	Male	Steady Negotiator (2)	High	Average	Average
	Zachary	Male		Very High	Low	Average
	Hailey	Female	Steady Negotiator (2)	Very High	Average	Low
	John	Male	Peer-supporting Reasoner (3)	Very High	High	Average
	Kimberly	Female	Self-contained Reasoner (2)	Very High	High	High

[1]Includes students not granted parental permission to participate in research
Note: Analysis focused on students in the shaded areas to account for within-group peer scaffolding

Communicative Inquirer. Communicative Inquirers share similarities with Quiet Inquirers, but tended to communicate more frequently across a wide range of topics within their groups. Whereas Quiet Inquirers used peer discussion primarily for project completion, Communicative Inquirers also engaged in casual discussions including off-task talks. Jade, for example, often facilitated the discussion and provided assistance whereas her partner, Paige was typically a receptive communicator. Jade's comments typified her motivation for her project as inquiry: "I think I'm a student that tries my best at everything and tries to give my best effort on projects because I enjoy doing them and I want a good grade on them." In contrast, Paige's commented infrequently, serving more as a sounding board and receiver of group communication and help as she remarked: “Jade helped me because she’s really good at the computer and I’m not very good at computer… I got help from people when I needed help” (post-interview, 03/28).

Self-contained Reasoners. In the preliminary studies, reasoners were able to build a deep, integrated understanding about the problem-solving topic but were unable to find or develop their own interest in the topic; their inquiry was characteristically less authentic and individualized than inquirers. In the current study, Self-contained Reasoners spent less time asking questions and talking to peers; rather, they focused on their individual projects. They spent more time than negotiators identifying meaningful problems, exploring and interpreting evidence, generating their own argument on the wolf population issue, and examining evidence carefully rather than depending on other’s opinions. However, compared to inquirers, they were less concerned about alternative perspectives and less motivated to think deeply about the subject matter or controversy. Contrasted with negotiators who rarely mentioned their shortcomings, Self-contained Reasoners identified both limitations and strengths in subject understanding and computer skills, and attempted to enhance both their knowledge and skill.

> I don’t know everything about the computer and… I’m not really good at naming all the parts of the computer. Like, I only know the printer, the keyboard and the computer (Justin, pre-interview, 3/3).

Peer-supporting Reasoners. Peer-supporting Reasoners were similar to Self-contained Reasoners, but they were more likely to share ideas and ask and answer peer questions. In contrast to Communicative Inquirers, they typically provided less depth in evidence-based investigation, expressed less interest and perceived less importance in the subject matter, and considered fewer alternatives. Jen’s remark typified these characteristics:

> I did not like the zone management [because] I just didn't understand it. It was like… they were talking about the… some of them on the premises stopped them being hunted. But some people just don't like wolves and we allow them to hunt all (post-interview, 3/30).

Both Peer-supporting Reasoners mentioned noted difficulty reading and understanding questions in Notes and evidence on wolf management. Allison stated: "What I didn't like was some of the questions had bigger words that I don't really know what they meant" (post-interview, 3/23).

Steady Negotiators. In preliminary studies, negotiators continually checked peers' answers and asked for teachers' help to confirm their own answers rather than investing their own effort. In the current study, negotiators sought other's input as the primary source of inquiry rather than focusing on investigating evidence and speculating on their findings. Steady Negotiators generally checked their answers and communicated with peers infrequently as they negotiated with other students during inquiry. They also showed less interest in project activities than inquirers or reasoners and were primarily interested in selecting pictures and changing backgrounds in their brochure design. Zachary's statement in the post-interview epitomized this trend:

> I really didn't like taking the notes. Except I learned a lot. But sometimes… the brochure was pretty boring. My brochure, it was pretty hard because there weren't a lot of good pictures that actually showed wolves (post-interview, 3/23).

Prompt Negotiators. Prompt Negotiators constantly shared their answers with peers to confirm accuracy and to complete projects quickly and with minimal effort. In contrast to Steady Negotiators, they solicited input and interacted frequently with peers as they inquired and completed their projects. Sydney's description on herself typifies such characteristics: "Just like a hard working student. I just like to want to get the work done." During the pre- and post-interviews, Sydney and Ashley expressed interest in enhancing their typing skills, representing themselves as a tech-savvy, and being prompter at completing tasks than their peers.

Unfocused Trial-and-error Students. In the preliminary studies, trial and error students surfed a great deal of information without a clear focus or goals. In the current study, Unfocused Trial-and-error Students completed the WISE investigation and project with little interest, intention, or focus. They paid little attention to project guidelines and spent a great deal of time on off-task activities (e.g., surfing websites irrelevant to the topic) and rushed to finish the project in order to use the spare time for online games. Steven typified this profile:

> Well, projects usually take a long time and I'm not very good at taking a long time at things unless it's video games or like a puzzle that's fun. I'm not weird video games but something like that but I'm not very patient with long things (pre-interview, 3/3).

The other trial-and-error student, Kevin lacked interest in the subject matter but enjoyed using technology in class.

> This project, I'd say it's kind of average because I'm not much of a wolf fan but I do like using the computer and going on the internet (mid-study interview, 3/10).

Classroom teacher. We identified three critical teacher characteristics: (1) experience and knowledge from prior profession; (2) teaching and learning beliefs grounded in constructivism and student-centered pedagogical strategies shaped by teaching practices; and (3) expectations and recognition of innovative teaching from students, peer teachers, and schools.

Prior experience as a scientist influenced Elizabeth's process of selecting the project, providing feedback on students' work, and her interactions with students. Prior to becoming a teacher, Elizabeth was in a Ph.D. program in neurobiology pursuing her career as a scientist.

After having classroom experience during her degree preparation and enjoying classroom teaching, she switched to a specialist's degree program in science education to become a school teacher. Due to her knowledge and experience in physics and biology, she expressed confidence in teaching science and in sharing her experience with students, most of whom were curious about how scientists work. However, she recognized that students rarely connect what they learn from textbooks with doing real-world science, nor do they bridge the gap between science in their everyday life and science in the lab: "If they draw a picture of what a scientist looks like, they are not going to be drawing me. They are going to draw a bald guy with glasses in a white lab coat" (post-interview, 3/30).

Therefore, one of her goals in the project was to help students revise their misconceptions about science: that science consists of unchanging, objective facts and that scientific method is a linear process.

> Interviewer: Do you feel your experience with science and science education influences your work?
>
> Elizabeth: Definitely. Because when you teach students about doing science, you teach them a scientific method. It's very a linear process but the real science isn't like that very often. So when we do talk about that process, I tell them "You don't check off your list of doing the part. There's a lot of you trying this, and if it's not working, trying that." It's much more complex. So I think my experience gives me credibility with them but also gives me that knowledge that that's not really how things work (post-interview, 3/30).

These goals and motivations influenced selection of the wolves project, where students could examine different perspectives surrounding a single issue and develop and test their opinions. Also, through the brochure requirement sheet [see Appendix B] and her responses to students' questions, she triggered students' thinking by asking questions such as: "Why?," "Based on what information?," and "What do 'you' think?"

Next, Elizabeth's perspectives, beliefs about effective teaching and learning, and pedagogical strategies were shaped by prior teaching experience. She believed that students learn best when they work on personally meaningful projects, often unavailable in classes due to insufficient time and limited opportunities. Therefore, she strove to help students develop both technical computer skills and to become "creative thinkers":

> I like to think I am a facilitator of learning—that I am not the person who stands in front of the room and says here's the facts and let's have a test on it. That's not my style. And the kind of class I teach also doesn't lend itself to that. And I like kids to discover things and I help them figure out how to get to the end but how they get to the end is up to them. I give them guidelines about what they have to do but there is a lot of freedom and flexibility for them. So I think I like to think that I am encouraging them to be independent and creative thinkers (post-interview, 3/30).

Elizabeth characterized herself as a facilitator of student learning. With the exception of class start-up time, she focused class time on answering individual student questions. Strategies for monitoring and challenging student work stemmed from her beliefs that students learn best when motivated and working on an interesting project while teachers provide guidance and expertise when needed. Elizabeth mentioned that she found WISE useful especially because she could choose a project from the database and modify it according to her students' needs.

Finally, the expectations, recognition, and appreciation she received from her students, from the technology coordinator, and from the school influenced Elizabeth's teaching practice. Though only her 3rd year teaching this class, she had already been recognized as teacher of the year. This course is known as a class where students do “cool stuff” and is recognized in the district for its innovative pedagogical approach that links technical skills, research skills, project-based learning, and students’ interests.

Research Question 1: How do middle school students identify, explore, and solve scientific problems in a Web-enhanced learning environment?

> “Well, I used to hate wolves but now I see that I… just because a movie, a scary movie that I shouldn’t hate them. And so… now they’re pretty cool” (Justin, mid-study interview, 3/10).

We identified four themes: (1) prioritizing and problematizing tasks; (2) framing and employing evidence; (3) monitoring and evaluating problem-solving activities; and (4) constructing and revising opinions/arguments. The four themes were found based upon the following procedures: (a) the researchers extensively examined all interview transcripts with the students from pre-, mid-study, and post-interviews and inscribed key ideas related to the research question (memo-writing) such as strategically selecting evidence, recalling relevant prior experience, and encountering difficulty with reading different positions; (b) then the researchers grouped the inscribed memos into relevant categories: memos related to task completion, memos related to self-monitoring, memos related to utilizing evidence, and memos related to revision; and (c) next, based on the memos, they identified sub-categories (e.g., concept-oriented vs. procedure-oriented) and renamed the four larger categories.

Prioritizing and Problematizing Tasks

Prioritizing and problematizing were evident during the first three phases of the problem-solving process: Problem Identification, Exploration, and Reconstruction. In the following, we contrast two aspects of students' inquiring and monitoring: (a) concept-oriented vs. procedure-focused, and (b) willingness vs. unwillingness to examine conflict.

Concept-oriented vs. procedure-focused. Students who were able to link their prior knowledge and develop in-depth understanding tended to focus on the core concepts of the topic (wolf management). Typically, inquirers and reasoners attempted to learn different perspectives on wolf management (e.g., farmers, environmentalists, and economist) and identify supporting information. In contrast, during mid-study interviews, negotiators and trial-and-error students demonstrated little interest in the subject matter, instead focusing on utilizing technology and completing their tasks. Unfocused Trial-and-error Students often concentrated on off-tasks, such as playing online games.

Inquirers and reasoners focused on critical concepts during their activities, noting that WISE provided problem context that guided their attention to concepts rather than procedures. One Quiet Inquirer (Jamie), who stated in the pre-interview that computers enabled her to focus on learning critical concepts in the subject, emphasized the efficiency of computer-supported activities in the post-interview again:

> Well, like we get to learn more about it because textbook sometimes doesn't always focus on what we're trying to learn. And when we learn on computers we can actually focus on one particular subject (pre-interview, 3/3).
>
> [Describing her experience with brochure design] I think you have a lot more things you can do on a computer than you can on computer. And it's a lot easier because if you're doing it by hand it'll take a lot longer to do what you're trying to do than if you were to do it on computer (post-interview, 3/21).

In contrast, Zachary, a Steady Negotiator, expressed his difficulties understanding WISE information and generating his own answer in the mid-study interviews. During problem-exploration and reconstruction, he wanted to enter the chat room which he was not permissible until he finished project tasks.

> I'm working on this … the wolf project and I'm doing my notes. And this is pretty tough to find out what to write. And I like … it gives you a lot of information, though. And I can't wait until I get to go in the chat room because that would be cool (mid-study interview, 3/11).

Students who focused on the procedures tended to have or develop little interest in the subject matter and project activities. One Unfocused Trial-and-error Student described online games as more entertaining than project work.

> Projects, projects, projects, projects, projects. Just projects. I'm not a really big fan of projects but when they're fun it's okay. But, still there's a lot of stuff you have to do by a certain point (Steven, pre-interview, 3/3).

Willingness vs. unwillingness to examine conflicts. When students found novel ideas or conflicting positions (e.g., farmers vs. environmentalists), inquirers and reasoners spent time attempting to comprehend the differences and rationale; in contrast, negotiators and trial-and-error students treated them as unimportant information. Leslie, a Quiet Inquirer, underscored the importance of utilizing WISE evidence (information) when she was confused:

> When we had to build the food chain. Because I didn't really know that much about wolves and I know that they ate some … I was really confused with that and I just put some down that I thought would fit on there. And some of them were right and some of them were wrong, but that just really confused me… I looked at WISE and I did food my

> chain and then I looked at it some more and found more information about it. And then I revised my food chain and I felt much better about the second one because I knew more about … because I felt more confident (post-interview, 3/24).

Framing and Employing Evidence

Two distinctions were found regarding students' finding, framing, and employing evidence during problem-solving: (a) Concrete vs. anecdotal evidence, and (b) strategic vs. incidental construction. These patterns were evident during Problem Exploration and Re-construction.

Concrete vs. anecdotal evidence. During problem re-construction, inquirers and reasoners identified and employed concrete evidence to support their position, whereas other students relied on opinions without evidence to support their argument. Students in both groups included multiple perspectives in their project brochures, whereas students in negotiator and trial-and-error groups did not. To a post-interview query about how contents of the project brochure were determined, Ashley, a Prompt Negotiator, stated, "most of the opinions [put in the brochure] I just knew off the top of my head" (post-interview, 03/28).

Strategic vs. incidental construction. Both Quiet and Communicative Inquirers tended to re-construct their opinions strategically and support their positions with evidence. In their brochures, they revisited and used WISE evidence to warrant their perspectives. Characteristically, they referred to rubrics (scoring criteria) for the brochure design task. Leslie, a Quiet Inquirer, described her strategies for designing the brochure:

> Thinking about different opinions, thinking through them, considering all the possibilities, and choosing or generating the best one (position) that seems logical…I just really thought about everything and I thought about the different opinions and thought

about why this one would be better than this answer and I just really thought through it and said, maybe this better than this because it seems more logical. Or it just seems better for everybody. I try to just think through it and see all the possibilities and choose the best one (post-interview, 3/24).

However, negotiators and trial-and-error students typically did not create online brochures sufficiently compelling to persuade policy-makers; instead, they expressed personal opinions. Compared to inquirers and reasoners, brochure evidence was rarely linked to their arguments.

Monitoring and Evaluating

Three themes were identified when students monitor and evaluate their activities and progress: (a) investigating vs. verifying answers; (b) constructive vs. superficial use of Notes; and (c) conceptual vs. nominal use of rubrics. These patterns were evident during Problem Exploration and Re-construction.

Investigating vs. verifying answers. During problem-exploration, the participants demonstrated diverse approaches to finding, filtering, and utilizing evidence. Clear distinctions related to motivation were evident among inquirers, negotiators, and trial-and-error students. While exploring problems and problem contexts, and re-constructing ideas and potential solutions, the four inquirers focused on the subject matter and conducted extensive in-depth investigations. Leslie (Quiet Inquirer) and Sydney (Prompt Negotiator) typified this contrast; while Leslie used evidence to revise her food chain, Sydney primarily used her prior knowledge or friends' answers.

[Leslie] Yes, I looked at WISE and I did food my chain and then I looked at it some more and found more information about it. And then I revised my food chain and I felt much better about the second one because I knew more about … because I felt more confident (post-interview, 3/24).

[Sydney] I just kind of thought about it and what they usually would eat. And I asked some of my friends and the teacher (mid-study interview, 3/10).

Negotiators and trial-and-error students spent the most time checking their answers with friends and focused on unrelated activities, such as improving their typing skills or searching for websites irrelevant to the project, rather than inquiring. Steven, an Unfocused Trial-and-error Student, searched for and went to his favorite websites when he felt "bored" with the project: "I just had to keep myself slightly entertained. And I would just go onto my favorite website" (post-interview, 3/24).

Constructive vs. superficial use of Notes. Inquirers typically used the electronic Notes embedded in WISE to save, revisit, and revise their understanding and opinions.

> I learned all about wolves and the management plan for them because if we hunt them then they're gonna … if we hunt them too much they'll be extinct. And if we don't hunt them then there will be too many. So .. and I learned it by reading somethings and then taking notes on it on WISE. And I think that was kind of fun because it was an interesting way to do it. Because you could go back and look at it and you could do that…I figured out the answers by looking back at the reading and looking at certain spots and making sure that it all .. that it answered a question correctly. And I think the WISE notes is a good way because you can look back if you wanted to do the brochure, maybe. If you wanted to put some of that on the brochure. And I just kind of thought it was fun (Jade, post-interview, 3/28).

In contrast, negotiators and trial-and-error students tended to view the Notes as a tool to complete assignments rather than to support their reasoning. One negotiator (Zachary) simply copied WISE text and pasted them into Notes. The teacher, in turn, encouraged him to answer the questions in his own words.

Constructive vs. nominal use of rubrics. While monitoring their own problem-solving processes, the participants used rubrics designed by the teacher and the researcher. However, rubrics were used in distinctly different ways. Inquirers and reasoners used the brochure rubric, which prompted to consider opposing viewpoints and rationales to frame individual positions on zone management, to brainstorm and generate ideas. In contrast, negotiators and trial-and-error students used the brochure rubric as a checklist. Ethan, a Self-contained Reasoner, emphasized the constructive use of rubrics:

> I figured out the information to put in the brochure by … I looked at the sheet I had to use for the brochure and I looked at certain things and then I looked back at what I had and I thought, I would put that in and that in. I singled out what I was going to put in and I copied that down and used that. Helps in the long run (post-interview, 3/22).

Constructing and Revising Opinions/Arguments

Two critical themes were identified regarding students' building and revising arguments: (a) multiple vs. single perspective, and (b) constructive vs. superficial collaboration. These patterns were evidence during Problem Presentation and Reflection.

Multiple vs. single perspective. Participants varied in their willingness to examine multiple perspectives and apply them to their project. All inquirers demonstrated interest in reading about different perspectives (e.g., farmers, environmentalists, economists, policy makers, etc.) on the same issue (i.e., wolf management); they routinely incorporated diverse positions to the brochure contents to support their argument. They also tended to revise their position after considering alternative perspectives.

> We found and solved like farmers' opinions and environmentalist's opinions. And we had to make our own opinion of … based kind of on … because of those. And we had to find out what our final solution was and if what we were going to do … what we thought we should do with the wolves and that was what we did.
>
> Well, I kind of already had an opinion where I felt like we should completely protect them. But then I read that if we do completely protect them, they might get a worse reputation than they do now. So, I read more and even though I do think it's not always good for wolves to eat livestock in that problem wolves maybe might need to be dealt with. Like eliminated those wolves. But, I read more information about them and I kind of evolved my opinion (Jamie, post-interview, 3/24).

Typically, negotiators and trial-and-error students neither attended to multiple perspectives nor revised their positions based on different perspectives, tending instead to reify rather than reassess their current opinions.

Constructive vs. superficial collaboration. Inquirers tended to challenge each other, sharing prior knowledge and their progress; negotiators and trial-and-error students concentrated on checking answers and finding resources that contained the "right" answers. Interview comments from Leslie (Quiet Inquirer) and Ashley (Prompt Negotiator) exemplify these differences:

> [Leslie] Basically, just reading what we had to read about them and then also Jamie told me a little bit about them because he loves wolves… She helped me with understanding some of the questions and she also helped me when we were building the food chain how

it kind of some things that would help and some things that ate also the wolves ate. She helped me with a lot of stuff… She told me what they actually meant and what they were asking in a way that I would understand it (post-interview, 3/24).

[Ashley] We … I think we tell each other our opinions and with the reading, like I said, some of us can read all of it. So, even if we didn't scan through it, we couldn't find the answer and we'd .. they would tell us, it's paragraph two, three and they would help you (post-interview, 3/28).

Research Question 2. How do they use different types of scaffolds (peer, teacher, and technology-enhanced) during their problem solving, inquiry processes?

"If I was looking for something, they would help me on the Internet try to find it. They (her peers and teacher) wouldn't do it for me but they would sort of guide me to where I was going and what I was doing so I could get it right" (Natalie, post-interview, 3/21).

Peer-supported Scaffolds

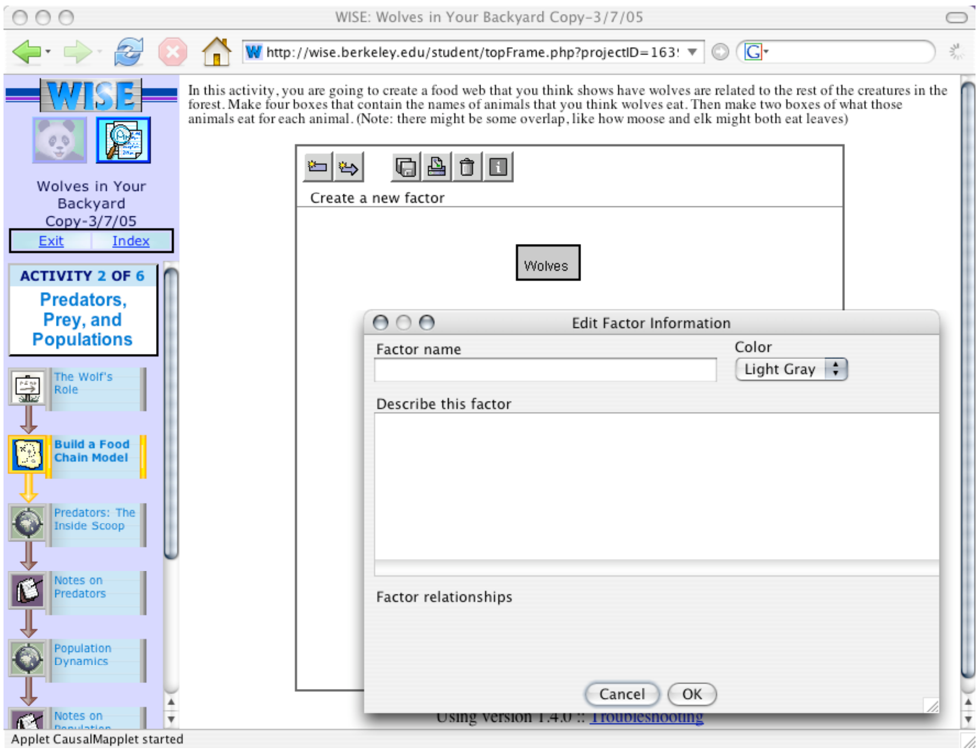
Four peer-support patterns were identified within and across groups: demonstration, procedural assistance, validation, and exchange of multiple perspectives. Demonstration, procedural assistance, and validation were typically affirmative and somewhat elementary, although they helped to expedite problem-solving processes. The exchange of multiple perspectives, however, helped to challenge and revise student ideas and their solutions. Table 4.4 aligns the major student activities during the project and the types of scaffolds they shared with peers.

Table 4.4. Alignment of problem-solving phases, student activities and peer-supported scaffolds

Problem-Solving Phases	Student Activities	Peer-Supported Scaffolds	Evidence
Identification	Learning about the wolf	- Demonstration & Procedural assistance (increasing tool familiarity)	Field notes Notes
Identification & Exploration	Predators, prey, and populations (food chain)	- Demonstration (creating and relating variables) - Procedural assistance (navigating)	Field notes Mid-study interviews Notes & Journal
Identification & Exploration	Wolf controversies (Notes)	- Demonstration & Procedural assistance (navigation, info-finding) - Validation (checking and confirming answers)	
Exploration	Management options (Notes)		
Reconstruction	What is your opinion? (brochure design)	- Demonstration (finding pictures and information and designing brochure) - Exchange of multiple perspectives (questioning and revising ideas)	Field notes Mid-study interviews Journal Artifacts
Communication/ Presentation & Reflection/ Negotiation	Discuss your own ideas (online discussion)	- Validation (expressing and confirming what they wrote in the brochure) - Exchange of multiple perspectives (questioning and revising ideas)	Field notes (Chat room discussion) Journal Post-interviews

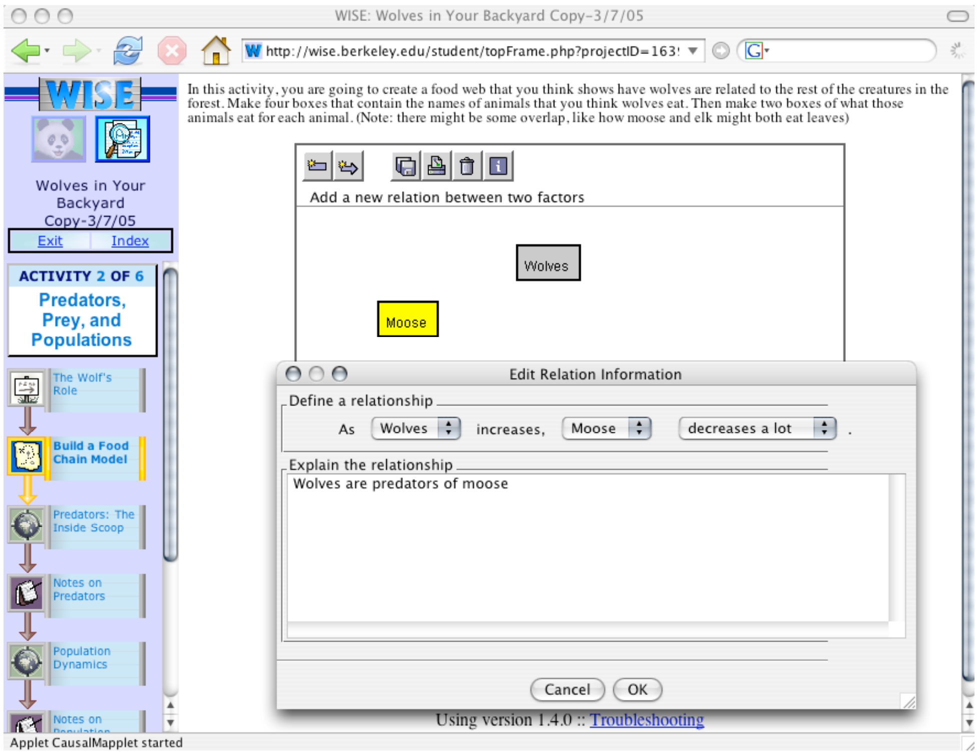
Demonstration. Demonstration was the most frequently observed peer scaffold, which typically involved asking/showing how evidence was located and technical problems wee addressed. Demonstration scaffolding was apparent when students worked on the food chain activity (Figures 4.13 and 4.14) and created an online brochure (Figure 4.15). These activities required that students employ computer skills, such as drawing shapes and lines, changing colors, move them on the interactive Web page and create HTML pages containing graphics and texts. Students frequently asked, “How did you do this? How did you change the color? Do you know how to get rid of this shape?" Sydney and Ashley (Prompt Negotiators), and Steven and Kevin (Unfocused Trial-and-error Students) provided or sought demonstrations most frequently.

Figure 4.13. Build a Food Chain Activity—"Edit Factor Information" Mode



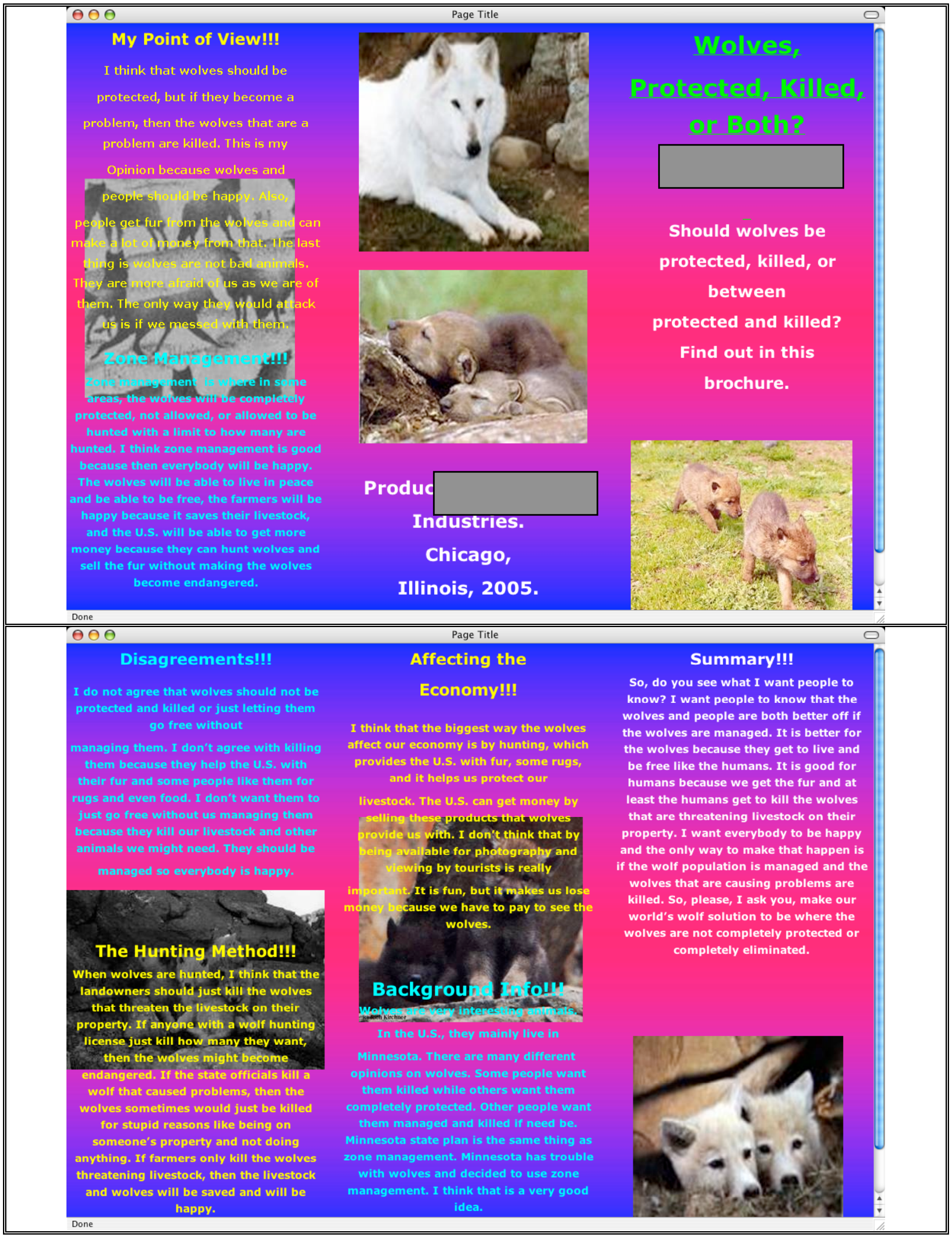
Procedural assistance. Procedural assistance was exchanged from problem-identification and exploration through reconstruction. At the beginning of the project, students helped each other learn to use the WISE system by asking "How did you log in? Where did you click on the first page? How did you get there?" Although the teacher demonstrated the major features of WISE, students initially encountered various technical and procedural issues. Subsequent procedural assistance typically focused on where to find answers. Negotiators attempted to skip the processes of identifying and exploring problems and immediately seek "right" sources that addressed questions they were answering in Notes.

Figure 4.14. Build a Food Chain Activity—"Edit Relation Information" Mode



Validation of answers. Validation scaffolding occurred most frequently when students generated and entered answers during activities 3 and 4. This was especially evident among negotiators who repeatedly checked answers with other students. Rather than exploring information or using WISE "Hints" which contained clues and suggestions for triggering ideas and answering questions, they tended to seek immediate confirmation from peers. Whereas negotiators attempted to validate their problem-solving through peers, Jamie, Leslie, Jade, and Paige (inquirers) typically challenged each other's opinions and shared perspectives gained from evidence.

Figure 4.15. Online brochure sample from Leslie (See Appendix E for all brochures)



Exchange of multiple perspectives. Although peer-supported scaffolding concentrated primarily on demonstration, procedural assistance, and answer validation, inquirers exchanged perspectives while they constructed artifacts (brochure). Peer scaffolding occurred when they shared artifacts with friends, compared them, and compared feedback on their structure, contents, and designs. Leslie, Jamie, Jade, and Paige's brochures described not only their position on wolf management (e.g., "Wolves should be managed," "Only state officials should kill wolves") but also perspectives from economist, hunters, livestock owners, tourists, and policy makers. Their artifacts reflect their capacity to interpret and accommodate the written evidence to their solution.

Students in other groups were less successful in seeking, understanding, or representing conflicting ideas and positions. During post-interviews, Jen and Allison (Peer-supporting Reasoners) expressed the difficulty due to contradictory opinions in their evidence and the amount of reading needed to understand and reconcile the differences. Interviews with Prompt Negotiators indicated they did not enjoy reading, comparing different ideas, or discussing them with peers. During problem-reconstruction, Peer-supporting Reasoners, Prompt Negotiators, and Steady Negotiators expressed frustration with developing their own solution to resolve conflicting issues.

Teacher-supported Scaffolds

Three patterns were evident in the researcher's field notes and from student interviews: clarifying the tasks and activities, monitoring students' progress, and challenging students' thinking. Table 4.5 aligns problem-solving phases with types of teacher-supported scaffolds provided.

Table 4.5. Alignment among problem-solving phases, student activities and teacher-supported scaffolds

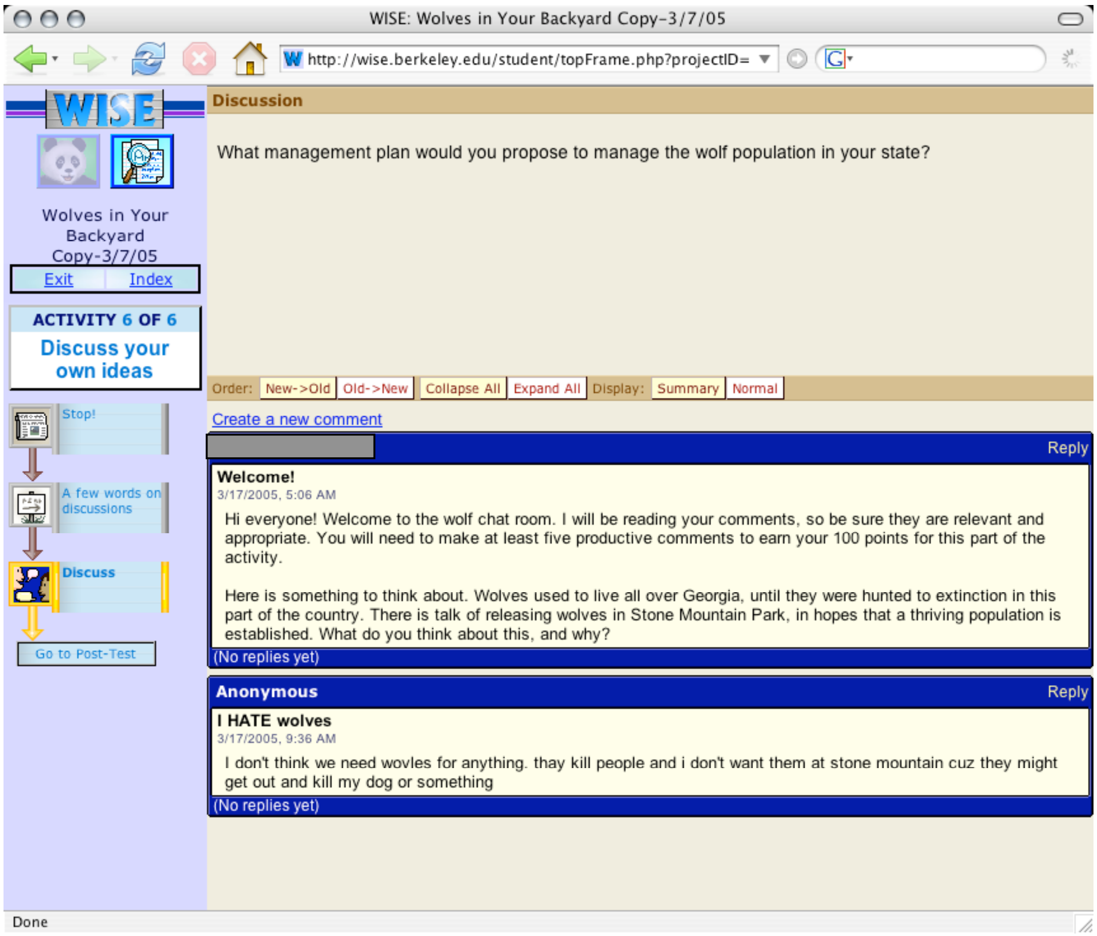
Problem-Solving Phases	Student Activities	Types of Teacher-Supported Scaffolds	Evidence
Identification	Learning about the wolf	- Clarification (getting familiar with the task and tool) - Monitoring (demonstration) - Challenging (motivating students)	Field notes
Identification & Exploration	Predators, prey, and populations (food chain)	- Clarification (Activity introduction and comments on progress) - Monitoring (navigation, info-finding, comments on progress) - Challenging (additional sources, relevant incident)	Field notes Mid-study interviews Feedback on Notes Journal
Identification & Exploration	Wolf controversies (Notes)		
Exploration	Management options (Notes)		
Reconstruction	What is your opinion? (brochure design)	- Clarification (Activity introduction and guidelines) - Monitoring (student discussion, requirement check) - Challenging (multiple perspectives)	Field notes (Chat room discussion) Post-interviews Journal
Communication/ Presentation & Reflection/ Negotiation	Discuss your own ideas (online discussion)		

Clarifying tasks and activities. Elizabeth scaffolded student problem solving by clarifying logistics and providing authoritative explanations. Since this class allowed students to work at their own pace, Elizabeth provided a project guideline sheet with which students could identify project goals and requirements from the first day of implementation. During the first five minutes of each class meeting, she provided an overview of the day's activities; during the last five minutes, she recapped the activities. Elizabeth also changed monitoring strategies as the students' work evolved. On the first day of the project, her assistance focused on identifying students who experienced difficulty understanding the WISE system, demonstrating where and how to save answers, and trouble-shooting problems (e.g., students registering twice, Web pages not showing up due to slow connection). On the following days, as the students became familiar with the WISE system, Elizabeth pointed out goals and guidelines of each activity and provided explanations for grades and comments for students' Notes.

Monitoring student progress. When students began to identify problems and explore evidence related to wolf management, most instructional time was spent commenting on individual progress and responding to questions about where to find relevant information and how to answer questions in Notes. Progress checking took place not only during classroom time but also after school; Elizabeth graded and annotated students' electronic Notes so that students could access feedback online and revise their answers. During problem reconstruction, students were permitted to join the online room only after Elizabeth reviewed each student's work and gave her permission. During the online discussion, monitoring was important to maintaining student focus on the subject matter. Elizabeth informed the students of her presence in the virtual discussion and warned of any improper use of language or expressions (e.g., Figure 4.16). Initially, students were curious about the identity of the "anonymous guy" (Elizabeth) who raised different perspectives (e.g., I HATE wolves); however, once they suspected it could be Elizabeth, they posted ideas to refute "his" points. Zachary's statement in the post-interview exemplifies student curiosity and excitement in Chat room:

> I think that it [Chat room] was really cool getting to talk with your classmates because everybody has different views. Most of the kids liked wolve though. A couple of kids didn't like it. But there was this one anonymous guy. I didn't like him. I even put up a comment, this anonymous guy sure seems to be a jerk (post-interview, 3/23).

Figure 4.16. Online discussion (Message and Anonymous posting by the teacher)



<u>*Challenging students' thinking.*</u> Finally, Elizabeth challenged students' conceptions by posing questions and sharing resources that encouraged further investigation. During the first two days while students attempted to identify problems, she motivated them by sharing provocative stories about wolf management (e.g., a potential plan for adopting wild animals in the near mountains reported in the local news). On days 2-4, the teacher identified additional evidence, consistent with or contradicting students' opinions, in order to model how to incorporate evidence to support a position. On project days 5 and 6, the teacher routinely checked students' progress on the brochure design and online discussion, and challenged them by raising perspectives counter to those expressed by students or within available resources.

Technology-supported Scaffolds

Based on individual student interviews and observations, four patterns were evident: tools as problem-context, metacognitive tools, processing tools, and communication tools.

Table 4.6. Alignment among problem-solving phases, student activities and technology-supported scaffolds

Problem-Solving Phases	Student Activities	Types of Technology-Supported Scaffolds	Evidence
Identification	Learning about the wolf	- Tools as problem-context (Embedded background information about wolves, guided Activities) -Metacognitive tools (Index, Notes, Activity goals) -Processing tools (Notes, links to resources)	Field notes Notes
Identification & Exploration	Predators, prey, and populations (food chain)	- Tools as problem-context (Modeling and visualization, embedded evidence about conflicting perspectives and Minnesota plan for wolf management, guided Activities) - Metacognitive tools (Index, Notes, Activity goals) - Processing tools (Notes, links to resources)	Field notes Mid-study interviews Notes & Journal
Identification & Exploration	Wolf controversies (Notes)		
Exploration	Management options (Notes)		
Reconstruction	What is your opinion? (brochure design)	- Tools as problem-context (Embedded evidence to support or contradict argument in brochure, artifact design, guided Activities) -Metacognitive tools (Index, retrieved Notes, Activity goals) - Communication tools (Chat room discussion)	Field notes Mid-study interviews Journal Artifacts
Communication/ Presentation & Reflection/ Negotiation	Discuss your own ideas (online discussion)		Field notes (Chat room discussion) Journal Post-interviews

Tools as problem-context. Students used WISE problems, tools, and resources as problem-context to find, frame, and resolve problems using embedded resources and evidence. On day 1, they primarily read online background information and identified discrepancies between what they believed (e.g., wolf as harmful animals) and what they learned (e.g., wolf size, weight, feeding, no evidence of attacking people). Beginning day 2, they examined wolf biology using a WISE modeling feature to create factors and relationships among wolf prey and predators. As they continued activities 3 and 4, students sought and read embedded current evidence and policies about wolf populations. These activities were structured using WISE's Index and visualized so that students could readily conduct their problem-solving activities without direct teacher guidance.

Metacognitive tools. During initial interviews, students noted feeling overwhelmed by the project and expressed difficulty getting underway. Three metacognitive features helped students focus on the tasks and learning. First, throughout the project, students used index and guided activities in WISE as a problem context in order to strategically plan their construction and revision of conceptual understanding (field notes, 3/16). Second, students used electronic notes to explore key questions and to receive guidance for saving and revising answers (field notes, 3/10). Ethan's statement exemplifies use of these features:

> [WISE Notes are] pretty useful because sometimes you might type something and then you want to add something else to it. Sometimes you go back and it's helpful because you can go back to it. Once you go past, it's not over … you can type it again (post-interview, 3/22).

Finally, they utilized activity goals on the first page of each activity and Elizabeth's WISE messages to concentrate on the problem-solving tasks and seek clarification. Zachary revised his answers in Notes once he realized he was not supposed to copy and paste text to answer questions, but needed to use his own words (mid-study interview, 3/11/2005). Elizabeth noted, for example:

> Hi everyone! You've done a great job getting started on the wolves project. I hope you like using WISE - isn't it nice that you don't have to worry about losing any papers or turning in your work? Remember to answer the questions carefully, and in your own words. Don't copy and paste your answers from the website; that is a clever trick, but it is not the right way to do things. Have a great day today! (field notes, 3/11/2006)

Processing tools. During the post-interviews, students reported that technology reduced the need for paper-based notes and textbooks. For example, Jamie's post-interview statement epitomized such advantages:

> I think you have a lot more things you can do on a computer than you can on paper. And it's a lot easier because if you're doing it by hand it'll take a lot longer to do what you're trying to do than if you were to do it on computer (post-interview, 3/24).

In particular, WISE processing scaffolds (Notes and links to resources) helped students to complete their work electronically without switching workspace from computers to paper-based materials. Both the teacher and students indicated that such scaffolds would save time turning in, looking for, and organizing papers and books. In addition, the links to additional web-based resources enabled students to quickly access reliable evidence they can use for answering questions in Notes and for designing their brochures.

Communication tools. Finally, the preference and frequency of Chat room utilization varied. While negotiators (Timothy, Zachary, and Sydney) spent most of their time reading and responding to other students' posting, most other students concentrated on finishing their project artifacts. Although most students expressed excitement about Chatting, they also faced challenges: occasionally slow network connections and deadline pressures for completing project requirements (field notes, 03/17). When students sought immediate support or feedback for their brochure design task, they primarily involved face-to-face discussion (field notes, 03/18). Chat room discussion was used to as a secondary source for sharing ideas (approximately 30% percent of the total discussion).

Research Question 3. What factors influence middle school students' inquiry in the Web-enhanced learning environment?

> "They [the activities in this project] are definitely different. The way they teach is different. The way you go about learning it's different. What you do while learning it's different" (Ethan, post-interview, 3/21).

To address the influence of foundation factors, we first coded interview transcripts, field notes, and student artifacts using memo-writing techniques (Glaser & Strauss, 1976) such as preference for reading about wolves, prior perception about wild animals, and consideration of local impact of wild animal management. These codes were grouped into the category called individual students' learning experience and strategies. The nested cases (individual students, teacher, task) and the umbrella case (web-enhanced classroom) in Figure 4.1 guided the identification of initial categories: individual students, group, teacher, tools and classroom and school. Then, we grouped and renamed the relevant memos under the five major categories as sub-categories. Finally, we renamed the major categories to reflect the characteristics of the sub-categories.

Student Learning Experience and Strategies

As shown in Table 4.7, five themes emerged: relevant prior experience, pedagogical strategies for exploring and reconstructing problems, social importance of the topic, enhanced computer skills, and available time and guidance.

Table 4.7. Factors influencing students' inquiry in the WELE

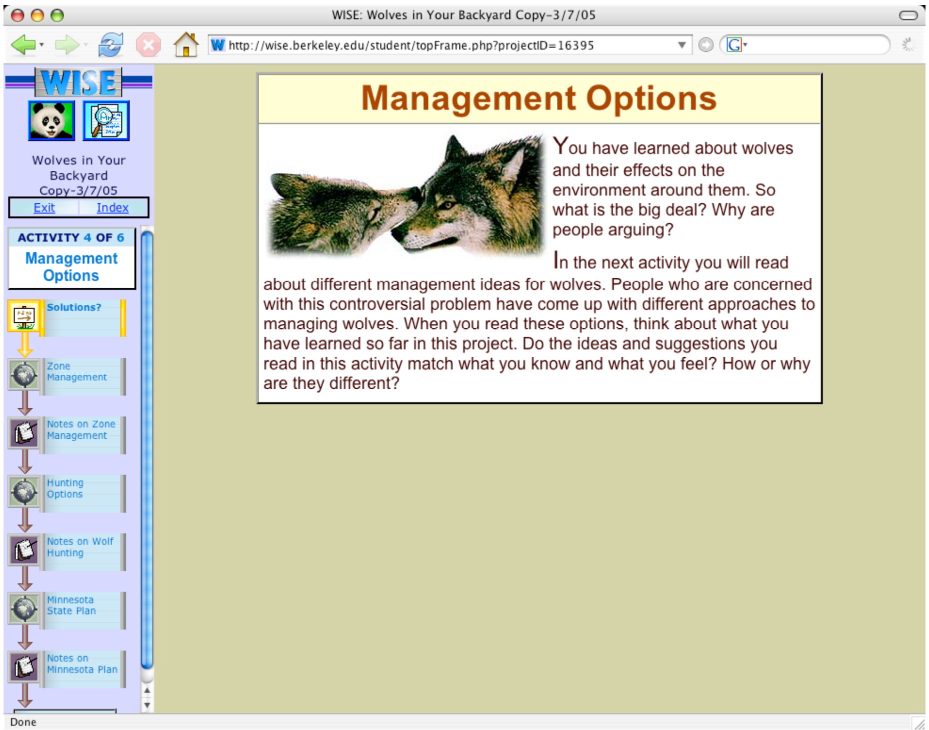
Categories	***Factors***				
	Psychological	***Pedagogical***	***Cultural***	***Technological***	***Pragmatic***
Student learning experience and strategies	Relevant prior experience	Pedagogical strategies for exploring and reconstructing problems	Social importance of the topic	Perceived importance of and interest in enhancing computer skills	Lack of time and guidance due to missing classes
Group collaboration pattern	Self-consciousness	Dominant vs. receptive role	Social value of cooperation	Online chatting	Computer lab setting Proximity
Teacher role	Trust	Monitoring Challenging Clarifying	Expectations and recognition of teacher	Knowledge and experience with tools	Classroom size
Design of tool	Assistance for reducing cognitive overload (notes, index)	Tool as problem-context, metacognitive scaffolds	Multiple perspectives embedded		
Classroom and school culture	Student perception of class as entertaining	Project-based learning in class	Support from teacher communities and school	Infrastructure (hardware, software)	Time and resources available for class

Students with relevant prior experience or who linked related previous experience with the project, psychological factors associated with prior knowledge and experience, tended to spend the most time exploring evidence. However, the quality and characteristics of the exploration and reconstruction of the problem varied. As evident in Table 4.3 (Participant Profiles), student interest in the subject matter (wolves) ranged from Very Low to Very High;

only one student identified their interest as Very High in the Pre-WISE Survey. Although during the post-interviews most students indicated their interest in wolf management issue increased due to the importance of the topic, Jamie, Justin, Timothy, and Zachary explicitly cited previous experience. Jamie had read extensively about wolves (e.g., novels) prior to the project and expressed Very High interest in Pre-WISE Survey. She was enthusiastic about the project, challenged her group partner (Leslie), carefully inquired into different perspectives on wolf management (Figures 4.17 & 4.18), and designed a brochure using a compelling argument and strong supporting evidence. Justin indicated negative previous experience with wild animals, describing them as “evil” based on movies and expressed Low initial interest in. However, his perspectives changed after he learned of no recorded incidents of healthy wolves having attacked humans. As a result, Jamie and Justin’s interactions with the inquiry tools were particularly focused and goal-oriented.

Figure 4.17. Example of Wolf Controversies page depicting different perspectives

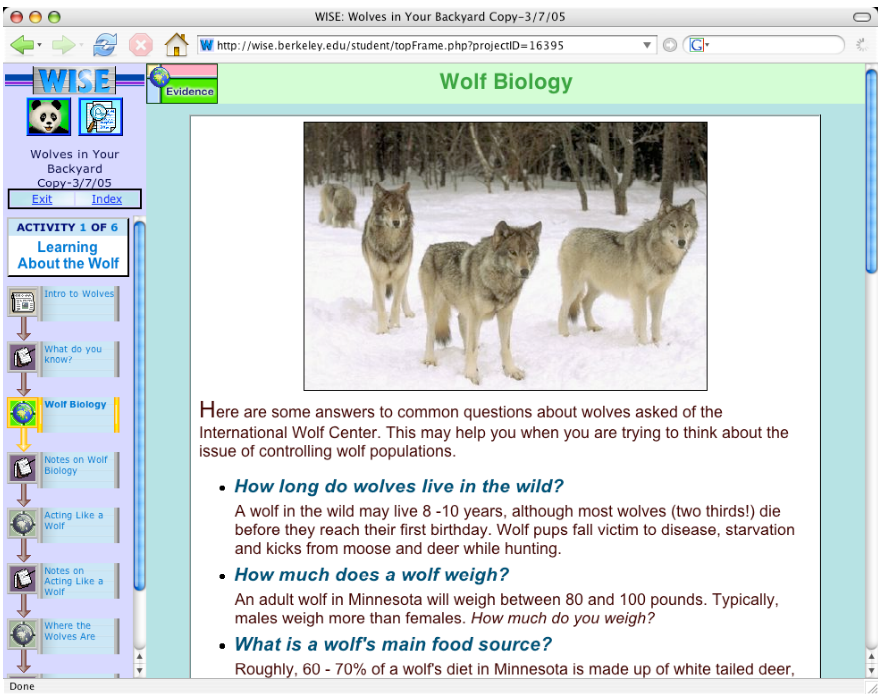
Figure 4.18. Wolf management plan activity



Other students recalled indirect experience with wolves; their interaction with the inquiry tools was less focused. Timothy reported Average interest in wolves despite having previously participated in his class's adoption of captured wolf in a nearby zoo. Zachary indicated Average interest in wolves, but recalled a magazine story about a woman who was hurt by wild animals, which he shared with the class on the second day of the project. However, in contrast to Jamie and Justin, both Timothy and Zachary spent less time investigating evidence and more time talking with friends either face-to-face or online. In addition, their end-of-project, online brochures were not as well detailed or supported as Jamie's or Justin's. Such differences indicate that prior experience and interest were not sufficient to promote meaningful, motivated inquiry.

Most students remarked that they had undergone conceptual change in their understanding and beliefs about wolves: from violent and destructive in their pre-interviews to inoffensive and nature-friendly in the mid-study and post-interviews. They attributed this change to wolf biology readings such as illustrated in Figure 4.19. Some students (Zachary, Steven, and Kevin) reported feeling overwhelmed by the amount of information to read and avoided links to other perspectives; other students (Jamie, Leslie, Jade), however, described the linked information as interesting and critical.

Figure 4.19. Example of Wolf Biology page that promoted conceptual change



Strategies for exploring and reconstructing problems were key pedagogical influences. As previously noted, substantially different inquiry activities were evident among inquirers, reasoners, negotiators, and trial-and-error students. Differentiated pedagogical strategies, shaped by previous project experience, individual learning patterns, and the learning styles of team members, influenced how students explored, interpreted, and documented evidence, as well as how they reflected on their learning processes.

Consistent with cultural foundations, when students perceived the social importance of the topic they investigated, their motivation increased. Most students rated their initial interest in the subject matter (wolves) as low or average. However, when the teacher shared local news about the possible release of wolves in a nearby mountain park on the second day of the project, student interest increased. They began to express concerns and ideas, and were more inclined to seek additional information. Motivation proved important in applying what they learned in class to their everyday lives.

Next, the opportunity to work with technology (browsing websites, typing answers, and designing publishable web pages in brochure format) motivated students. During pre- and post-interviews, most participants mentioned the goal to be skillful in utilizing computers. All participants indicated that recording Notes online provided opportunities to practice typing skills and to track answers. In addition, they liked developing the online brochure since they could focus on the content rather than being concerned about poor drawing (Leslie), could change colors and designs quickly (Sydney), and could pick and include preferred pictures and images (Steven).

Finally, pragmatic issues, such as the time allotted and guidelines provided, influenced students' technology-enhanced inquiries. In general, students had sufficient time to finish tasks and revise brochures. However, when Ashley and Jen missed classes or lacked time to explore and reconstruct, they sought assistance from friends to "catch up." Still, both reported difficulty completing their project brochure-design on time (field notes, 3/21). In contrast, pedagogical accommodation appeared to mitigate time constraints. During post-interviews, students often mentioned that the guidelines developed by the teacher and researcher (e.g., posing essential questions, task rubrics) helped them to focus and expedite task completion.

Group Collaboration Patterns

We identified five within-group themes: self-consciousness (psychological factor), roles in group (pedagogical factor), social value for cooperation (cultural factor), online chat (technological factor), and the computer lab settings and proximity (pragmatic factor). Self-consciousness was apparent within the Prompt Negotiator Group. Sydney and Ashley worked together with the other student. They constantly checked each other's progress on the project and wanted to finish the task as quickly as possible. During the post-interviews, Ashley expressed concern about potentially inadequate technology skills, and cited improved typing speed as a goal. The online brochures created by Prompt Negotiator group shared similar contents and formats: they organized the survey results about other students' opinions on wolf populations by grouping them into three—Keep them, manage them, and take them out.

When students worked together, interactions were influenced by individual learning strategies. In the Communicative Inquirer and Prompt Negotiator groups, where communication was most frequent, typically a verbally fluent student took a lead role in sharing ideas and persuading others. For example, Jade elaborated her answers in Notes and explained her rationale; her partner, Paige, applied these ideas to hers. Although Sydney and Ashley's collaboration pattern was somewhat different (Sydney's statements were declarative rather than not elaborative), Sydney as the verbal team member led the group.

Students helped each other within group, yet their motivation stemmed from different sources such as self-confidence and consciousness, and intrinsic interest in the topic. One salient source was students' perception of the social value of collaboration. During pre-interviews, several students cited the benefits of collaboration in fixing problems and sharing ideas and acknowledged its importance in everyday life.

> Like … well, in scouts I have a lot of friends there and the motto is “Do a good turn daily.” In other words help somebody daily. And that helps because everybody is wanting to help you and stuff (Justin, pre-interview, 03/03).

Technology affordances such as online chat also influenced students’ inquiry in groups. Upon finished their online brochure, students were able to participate in online-chatting to share their positions on wolf management. Although during post-interviews students reported that it was fun to chat in class, they also identified limitations of online chat such as frequent off-task discussions and lack of compelling argument with supporting evidence.

Finally, pragmatic factors such as the computer lab set-up and proximity between students increased students’ inquiry in groups. Every student had access to an individual computer, and group members sat nearby each other. They interacted (e.g., talked and listened) with each other while working individually at their own computers.

Teacher Role

Trust in the teacher allowed students to feel free to questions in class. The students reported feeling proud that they were taking this course, and that other students and teachers recognized the uniqueness of Elizabeth’s innovative practices (field notes, 3/16). Elizabeth scaffolded both individual and group project efforts in selecting and customizing inquiry tools, monitoring problem-solving processes, challenging perceptions on the wolf population, and providing clarifying assignments and tasks. In addition to these pedagogical factors; thus she facilitated both students’ problem solving processes and co-constructed scientific knowledge and understanding. Most participants mentioned in pre- and post-interviews that they respected and could learn from Elizabeth’s extensive knowledge and experience with both science and technology. However, in practice Elizabeth's facilitation and support were limited due to multiple, simultaneous students seeking assistance at the same time.

Design of Tools

According to the technology-supported scaffolds discussed in research question 1, tools influenced students' problem-solving in class. Psychologically, by using electronic WISE Notes and Index, students were able to manage the cognitive load associated with their investigations. Pedagogically, inquiry tools served as a problem-solving context; metacognitive scaffolds (structured activities, Notes, and Index) and processing scaffolds (Notes and links to resources) helped students to find, framed, and solved problems. As cultural foundation factors, it was essential for students to be able to use the tools to find and examine multiple perspectives on a single issue from different people (e.g., farmers, environmentalists, economists, and tourists).

Classroom and School Culture

Using field notes and interview transcripts, we identified five factors that influenced students' inquiry associated with classroom and school culture: student perception of the class (psychological factor), project-based learning in class (pedagogical factor), support from school (cultural factor), infrastructure (technological factor), and time and resources support for class (pragmatic factor). Students' perceptions of the class as fun and entertaining influenced their inquiry activities in constructive ways. They reported satisfaction with the freedom and flexibility to select their own class projects, and noted that the uniqueness of this course made them "happy" when they entered the classroom (Steven, pre-interview, 03/03).

The epistemological-pedagogical nature of the classroom, which provided numerous opportunities for project-based learning, motivated students to link their individual interests to the project requirements and to conduct in-depth investigations of meaningful problems. Based on past project experiences, such as Invention Convention, where students created a useful device, students appreciated the chance to learn at their own pace and to spend time exploring what they wanted to know. Allison's pre-interview statement captures the personal investment of students: "You get to put your creativity in it and it's not somebody else's. It's just… well, yours" (pre-interview, 3/2). Students also found the online brochure project useful because they could design it in creative and flexible ways. Justin's post-interview statement also illustrates the benefit of this class in allowing him to conduct in-depth investigation: "Because you go more in-depth and you do fun stuff, not just homework stuff, and as I said, you go more in-depth into it. And you just spend two weeks on it and go to something else" (post-interview, 3/22).

Finally, students identified the importance of support from the school, which provided the infrastructure, time, and resources for this class. During pre-interviews, most students acknowledged that taking the classes was a unique opportunity in that they were qualitatively different from traditional classes.

Discussion

Problem Solving in Inquiry-Supported WELEs

Previous research indicates that students encounter challenges while utilizing technologies in science classrooms. For example, Clark and Linn (2003) indicated that typical 8th grade students had difficulty learning about "normative" (p. 482) science concepts (e.g., thermal equilibrium, thermodynamics) and integrating new science knowledge into "experiential knowledge" (p. 480) grounded in everyday life. The researchers concluded that considerable time and carefully designed pedagogical practices are needed for students to revise their naive theories.

This present study revealed similar challenges where the patterns and strategies of 6th graders' scientific problem solving and reasoning varied substantially. Prior experience and interest proved important in identifying, exploring, and solving authentic science problems. Jamie, a Quiet Inquirer who reported "Very High" interest in the subject matter (wolves), subsequently motivated her partner (Leslie) to recognize the importance of the problem-solving topic (wolf management). While most students reported the project to be interesting due to the Web-based problem context (WISE), they typically did not engage deeply in inquiry related to the problems under study when they neither had nor developed interest in the subject matter.

Gordin and Pea (1995) also cited the importance of prior knowledge in research examining high school and undergraduate students' use of a visualization tool (SciV) to engage in inquiry related to climatology (e.g., "What is the relation between solar radiation and the Earth's temperature?", p. 267). They reported that students difficulty manipulating data and interpreting climate visualizations was influenced by limited knowledge regarding the basic measurement concepts (e.g., meter, kilogram) and prior concepts "that interfere with their ability to make sense of scientific phenomena they are examining" (p. 270).

Next, problems encountered in examining and linking relevant evidence to personally-relevant problem contexts was influenced by limited strategies and understanding of inquiry. In this study, only select students developed interest in the subject matter during the project and were willing or able to engage deeply in the inquiry tasks. Negotiators, Zachary and Timothy, became motivated about the project after recalling their relevant memories, but still failed to carefully seek or examine evidence. In contrast, Justin, a Self-contained Reasoner, increased his interest level and explored the positive aspects of wolves (e.g., not attacking people, benefiting the economy). Subsequently, he articulated and reflected during inquiry tasks using WISE scaffolds such as evidence and the visualization and modeling tool.

A key distinction lies in the focus of inquiry and subsequent pedagogical strategies. Negotiators followed procedures and completing tasks, whereas inquirers and reasoners examined conflicting evidence and integrated concrete evidence in their artifact designs. This distinction has been characterized as "sense-making" (Hannafin, Land, & Oliver, 1999; Quintana et al., 2004); that is, in order to make sense of natural phenomena or scientific theories, students are exposed to anomalies, experiment with theories, and resolve conflicts. Inquirers and reasoners have developed and refined sense-making strategies for problem solving through iterative revision. As experienced "experts," they became skillful at identifying meaningful problems and connecting conflicting evidence to the problem contexts; negotiators and trial-and-error students ("novices") had not previously and did not during the current inquiries related to wolves (cf. Chi, Feltovich, & Glaser, 1981; Quintana et al., 2004).

Scaffolding Scientific Problem Solving in WELEs

Research on scaffolding in classroom-based TELEs indicates that students can benefit from different types of scaffolds such as student-teacher interaction, student-tool interaction, teacher-tool interaction, and peer interactions (Kim, Hannafin, & Bryan, in preparation). According to Reiser's (2004):

> A first critical factor is that the ways of thinking the tool is designed to support must be threaded through all aspects of the classroom system—in the curricular activities that surround the tool, in teachers' support working with individual groups, and in the teachers' structuring and guidance of whole class discussions (p. 288-289).

Our findings suggest that peer-, teacher-, and technology-supported scaffolds were helpful for 6th graders' problem solving in project-based science classrooms. Through peer scaffolding, students were able to confirm answers, confront and reconcile conflicts, encourage and challenge further thinking, and share perspectives. Through teacher scaffolding, students were able to monitor progress, revise answers, remain on task, and become motivated to refine strategies and investigate evidence. Technology-based scaffolding, embedded in the WISE tools, helped students to externalize and visualize their understandings, find and locate resources, save and access notes, and manage cognitive loads.

However, scaffold use and effectiveness varied according to individual problem-solving strategies and group collaboration patterns. Two technology-supported scaffolding strategies proved useful: (1) visualizing evidence with structures, and (2) incorporating a causal mapping tool into problem-solving contexts. Several students experienced difficulty reading the text-based evidence embedded in and linked to the WISE program, especially when presenting diverse or contradictory perspectives. However, by recording their progress in Notes, they were able to make their understanding and progress visible, creating an artifact embodying both their positions and evidence regarding wolf management. This finding is consistent with Bell and Linn's (2000) description of students' use of *SenseMaker* in the Knowledge Integration Environment (KIE) project. *SenseMaker,* designed to support students' modeling, assisted students as they probed into historically documented conflicting positions on light (e.g., "Light goes forever" vs. "Light dies out," p. 799) using accompanying visual representations of core theories, evidence, resources, and tools. The researchers reported that students were better able to articulate arguments using the different frames (e.g., "conceptual, categorical, debate, and unique critique," p. 806) afforded in *SenseMaker*.

During the food chain task in the present study, students manipulated factors and relationships thus elaborating understandings of predators, prey, and their relationships in a manner similar to Linn, Clark, and Slotta's (2003) causal mapping tool. Although they readily learned basic definitions, the modeling feature enabled students to contextualize and examine the impact of the wolf population on the entire ecosystem. Consistent with scientific investigations using modeling tools, concept mapping has been regarded as an effective instructional strategy in science education to help students study relationships among core concepts and detect and revise "Limited or Inappropriate Propositional Hierarchies (LIPH's)" (Novak, 2002, p. 548). Furthermore, Toth, Suthers, and Lesgold (2002) demonstrated that 9th graders who used *Belvedere* mapping strategies better connected evidence to tentative theories and manifested stronger reflective reasoning and argumentation in their problem-solving processes than those using traditional writing.

Two teacher-supported scaffolding strategies were also found to be especially effective: (1) providing clear guidelines and leading questions, and (2) customizing the problem context to students' interests and needs. Project rubrics and brochure requirements helped students to monitor their learning by stepping through and answering critical questions. For example, one question asked, "In your opinion, is zone management (wolves are protected in some zones but not others) a good solution for the wolves in your area? Please explain answer with evidence from the project." This scaffold induced student reflection on their perspective and guided them to seek evidence to confirm or disprove their opinions. In an attempt to align classroom rubrics to the goals of inquiry (NRC, 1996), science educators have proposed frameworks to guide teacher scaffolding of students' inquiry. For example, Chin and Malhotra (2002) identified four student inquiry tasks (i.e., "authentic inquiry, simple experiments, simple observations, and simple illustrations" p. 188) and argued that assessment is needed to promote authentic inquiry.

Technological affordances that allow teachers to customize tools have been developed to accommodate different teaching strategies and to transform the teacher's role from knowledge source to facilitator of student learning (Linn, Clark, & Slotta, 2003). In our study, we modified and adopted a WISE project based on the lessons learned from the three preliminary studies. In previous studies, few students responded to scientific problem solving or to inquiry-oriented argumentation. In addition, they tended to skip problem exploration and engage in discussion without examining evidence beforehand. Thus, we incorporated issues directly related to students' everyday lives to motivate them (e.g., local issues of wolf release plan and management) and monitored students as they completed key questions to ensure they identified appropriate evidence before joining online discussions.

Finally, the problem-solving patterns of individuals working in groups can differ substantially from those who work independently. For example, in the Communicative Inquirer group, Paige was quieter and more passive than Jade, who expressed her opinions eloquently. However, when they worked together, they share work and comments. Thus, Paige's artifact was well-designed and articulate, and reflected the product of constructive collaboration. In the Quiet Inquirer group, Jamie's high interest in wolves was evident when Jamie discussed the stories related to wolves that she had read from books and magazines. This influenced Leslie's inquiry, which became more focused and meaningful during problem identification and exploration.

Students also influenced each other's inquiry in other groups, but in somewhat different and occasionally undesirable ways. Sydney and Ashley, partners in the Prompt Negotiator group, were less focused on inquiry activities, instead concentrating on task completion and repeatedly checking each other's progress. Steven and Kevin, who worked in the Unfocused Trial-and-error groups and were interested in online games, constantly talked about resources for interesting pictures and games, rather than the subject matter. In effect, "group-think" appeared to dominate individual inquiry.

Previous research has confirmed the influence of ongoing interaction and communication on the focus and depth of individual inquiry activities. Oliver and Hannafin (2001) reported that heterogeneous ability dyads can complement a low student's performance, but that homogeneous dyads tended to collaborate less productively. Similarly, Wallace, Kupperman, Krajcik, & Soloway (2000) found that when 6^{th} graders collaborate to find and utilize online resources for their inquiry, they tended to be competitive and raced to identify Web pages that contained correct answers rather than exploring diverse resources and developing deep understanding.

Implications for Research and Practice

Contrary to the findings from a 3-year, large-scale study of systemic science education reform in Detroit public schools, in the current study it proved particularly challenging for under-performing students to understand the inquiry processes and utilize technology to improve their understanding. In the Detroit study, both low-achieving and high-achieving students' post-test scores increased after utilizing technology-supported curriculum in science classes (Marx, Blumenfeld, Krajcik, et al., 2004). This may be due to differences in the time students spent with the WELE and the scaffolding provided to support inquiry, challenge conceptions, and address misconceptions. Students require significant time and opportunities to develop and apply inquiry practices to identify anomalies between evidence and experience, resolve the conflicts, and develop, deep coherent understanding (Clark & Linn, 2003). The current study documented both the initial emergence of inquiry practices from negotiators and trial-and-error students, and the entire inquiry process from inquirers. Thus, research is needed to examine the emergence of processes of under-performing students (e.g., negotiators and trial-and-error students) as they begin to understand and enact inquiry practices.

A second implication for research and practice is related to helping students to link relevant daily experiences to problem contexts. Technology-supported problem-solving environments can encompass a wide array of resources and strategies to help students to associate their own experiences with meaningful scientific problems. In our study, the teacher presented an authentic problem-solving scenario by sharing local news about the possible release of wolves in a nearby park. This had an almost immediate and positive impact on the students' motivation, especially those with initially limited prior knowledge, experience, and interest. In open-ended learning environments, where students identify their own interests, meaningful problems, and driving questions, the importance of explicit guidance may be overlooked. In order to help students (especially under-performing students) enhance their interest in the subject area, it is essential to provide clear cues and illustrations that help students to relate their everyday experience to the problem contexts.

Increasingly, researchers and practitioners have sought to understand and clarify the teacher's role in inquiry-supported TELEs (Songer, Lee, & McDonald, 2003). In their study of eight 7^{th} grade students in project-based inquiry science classes, Krajcik et al. (1998) reported student "failures to focus on the scientific merit of questions generated and to systematically collect and analyze data and draw conclusions" (p. 313). However, they suggest the teacher scaffolding strategies through "structuring" and "questioning" to be essential in helping students practice inquiry. Further research is needed to examine teacher guidance in technology-supported science classes, which can differ substantially from traditional science classes.

In the current study, peers also scaffolded students' problem-solving inquiry processes. Research suggests that peer scaffolding may help to further clarify meanings, share diverse positions, and monitor students' learning processes (van Zee, Iwasyk, Jurose, Simpson, & Wild, 2001). In the current study, teacher support was most positively rated by students, but peers also augmented teacher scaffolds and provided unique student perspectives. Peer scaffolds were particularly useful when they aligned with the teacher's project goals and pedagogical approaches. Thus, this study suggests that peer-supported scaffolds may be more effective when students share the goals and objectives of project activities, with teachers and among peers, and understand the benefits of exchanging perspectives and challenging each other.

Research on technology-supported collaborative inquiry suggests that promoting constructive collaboration in middle school science classes requires a "classroom culture" where students actively engage in inquiry while teachers facilitate their learning (Kolodner et al., 2003). Two implications are especially relevant for facilitating group inquiry. First, in technology-enhanced learning environments, students may benefit from an emphasis on the quality of evidence and argument rather than the number of data points or the frequency of communication. Peer- and teacher-assessments of inquiry activities or guidelines for group collaboration might be useful to examine the nature and quality of group interaction, and ultimately to scaffold interactions effectively. Next, in our study group activities and communication influenced formatively how students communicated. In effect, an informal community emerged and communication conventions evolved that failed to reflect the scientific mores inquiry was designed to engender. Instructors can provide exemplars of knowledge articulation and scientific argument before students develop communication conventions in their groups. It is important to examine the influence of informal, peer-based conventions on the emergence of (or resistance to) students' scientific reasoning and conventions.

Cautionary Notes

The purpose of this study, as a qualitative case study, was to examine students' problem-solving patterns and strategies, types of supporting scaffolds, and the impact of foundation factors in unique classroom settings. There were four unique aspects of this study: (1) the capacities and characteristics of students as gifted, (2) the teacher's extensive prior knowledge in science, (3) the uniqueness of the curriculum for this class, and (4) the influence of the researcher's perspective on interpretation and analysis.

First, students in both classes were academically gifted students, and elected to take the advanced course. Gifted students generally have greater prior knowledge and more advanced study strategies than typical students. In addition, they registered for the primarily due to their interest in technology and a good reputation of the course as being flexible.

Second, the teacher had both extensive content and science process knowledge in biology. As discussed in Participant Profiles, she was previously involved in a doctoral program and worked as a research assistant in a science lab. After finding teaching experience to be rewarding and meaningful to her, she pursued a Specialist degree in science education. This allowed her to link her prior knowledge and experience as a scientist to this classroom teaching. Third, as an elective course for gifted students, the goal of this class is to provide research experience through computer-based technologies and strategies for finding, filtering, and employing information in the research process. The teacher promotes project-based learning, open-ended tasks, and student-centered learning. This is not characteristic of many regular science classes where the pressures of standardized testing and competing curricular priorities may limit opportunities for project-based learning.

Finally, due to the qualitative nature of this study, researcher bias is possible in any qualitative study. Since qualitative studies do not strive for "generalizability" in the traditional sense, I have attempted to promote "reader generalizabilty" (Merriam, 2002) by providing a vivid description of both my perspective and the setting and methods.

Conclusion

This study indicates that middle school students' cognitive and social processes, as well as specific activities and strategies used in TELEs, vary substantially when engaged in scientific inquiry. This study also suggests that inquiry can be supported by guiding structures of activities, concrete examples of evidence and inquiry processes, and specific questioning strategies for monitoring and challenging students provided by tools and instructors. In addition, in designing and facilitating TELEs that promote problem solving practitioners need consider how foundation factors align with scaffolding activities to maximize their interplay in supporting and impact on students' problem solving.

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APPENDICES

A. CONFERENCE PAPER (AERA, 2005)

B. DATA COLLECTION MATERIALS

C. INTERVIEW PROTOCOLS

D. SAMPLE FIELD NOTES

E. EXAMPLE DATA ANALYSIS OF SELECTED STUDENTS

APPENDIX A.

CONFERENCE PAPER

PRESENTED AT THE AMERICAN EDUCATIONAL RESEARCH ASSOCIATION (AERA), MONTREAL, CANADA

What Factors Shape Interactions between 7th Graders' Problem Solving and Inquiry Tools: The Case of a Web-enhanced Learning Environment

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Introduction

The World Wide Web has transformed the way people think and communicate in this information society and in schools (U.S. Department of Education, 1996, 2000). Googling has become one of the most popular, quick ways to locate information and to start thinking about a specific topic, and emailing and online chatting have been regarded as convenient modes to talk to people. In education, the National Report on Teachers' Use of Computers in public schools indicates that students (grade 4 and 8) use computers most frequently to write drafts of their assignments in schools, to read stories on the Web, and to practice basic skills such as spelling and grammar (U.S. Department of Education, 2000). Despite the fact that 99% of public schools in the United States have access to the Internet and the fact that researchers emphasize the value of computers as cognitive tools to promote students' *thinking* skills, the National Report shows that the uses of computers and the Internet in schools are still at the basic level; they are used as simple machines for word processing and information displaying.

In science education, the tension between fostering students' problem-solving skills (inquiry) and using computers and the Internet in class has increased because of, to name a few, the lack of guidelines for each subject matter, teachers' lack of time and resources, and students' lack of metacognitive capacity. Given the problems that computers and the Internet have seldom been used in science classes as problem-solving tools in cognitive ways, the purposes of this study are to understand why students have difficulty using computers as cognitive tools and to fill the knowledge gap between the proliferation of Web-based tools and the lack of guidelines for designing web-based tools for problem-solving.

The main question that guided this study was what factors shape the interactions between students and web-enhanced inquiry tools when middle school students solve scientific problems with Web-enhanced learning environments. To explore this question, WISE (Web-based Inquiry Science Environments)[2], one of the Web-based learning environments designed for fostering students' scientific inquiry activities, has been selected to facilitate students' problem-solving because it supports research-based, scaffolded inquiry processes.

Literature Review

Proponents claim that the World Wide Web promises a great deal of learning and teaching opportunities from online course syllabi to digital libraries[3], from self-reflective online journals[4] to discussion boards[5], and from teacher-designed course materials[6] to student-centered interactive tools[7]. The unique features of the World Wide Web, typically named as convenience, accessibility, and interactivity, have been regarded as the benefits that students and teachers gain from numerous online learning environments (e.g., Gordin, Gomez, Pea, & Fishman, 1996; Hoffman, Wu, Krajcik, & Soloway, 2003; Lea & Scardamalia, 1997; Linn, 1996).

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[2] WISE (Web-based Inquiry Science Environments), funded by National Science Foundation, was developed by Marcia Linn's research group in U.C. Berkeley. I received permission from her and her research group to use this inquiry tool for my research.
[3] For example, see Galileo at http://www.galileo.usg.edu/
[4] For example, see Webblogs at http://blogs.usu.edu/students/uga/minchi.kim/
[5] For example, see SWIKI at http://minnow.cc.gatech.edu/swiki/
[6] For example, see WebQuest at http://webquest.sdsu.edu/
[7] For example, see SimCalc http://www.simcalc.umassd.edu/

Despite the WWW's affordances, many researchers argue that the challenges of utilizing web-based tools stem from a tendency that people rarely use complex thinking (Bransford, Brown, & Cocking, 2000). In particular, students in schools face various issues, to name a few, cognitive overload, limited self-regulation capacities, and a lack of problem-solving thinking. Typically students are allowed to surf the WWW to find answers to questions posed by teachers but rarely use their metacognitive strategies to refine their thinking. Research shows that students tend not to construct their own higher-order thinking (Oliver & Hannafin, 2000) although they feel interested in learning with the WWW. The large amount of information that students are expected to process for solving problems can be problematic as can students' developmental unreadiness to digest the information.

Kim and Hannafin (2003) also classified computer technologies for science into eight types based upon the purposes of the technologies: seeking tools, collection tools, processing tools, organization tools, integration tools, manipulation tools, generating tools, and communication tools. This typology was designed not only to identify different types of science tools but also to help analyze students' cognitive activities using the tools to solve problems. Inquiry plays an important role in interpreting learners' cognitive activities because many of the science tools are designed to promote scientific inquiry processes by providing scaffolds.

Although this paper presents numerous types of tools, identical tools can serve different functions according to the diversity of the learners, learning styles, and learning contexts. For example, WISE (Web-based Inquiry Science Environments) help students not only integrate their knowledge but also visualize scientific concepts and collect data from websites designed by scientists. Also, WISE facilitates communication between students and scientists, which gives students authentic learning experience in communities of practice.

No one would disagree that understanding how students develop problem-solving skills in Web-enhanced learning environments for science requires a comprehensive review of previous research from the fields of instructional technology, educational psychology, and science education. This section, in particular, focused on students' challenges related to using WELEs for fostering problem-solving and different types of Web-based tools for science. Further research is needed regarding how each type of web-based tools interacts with middle school students' problem-solving processes and, in particular, inquiry processes in science.

Methods

This study was designed as descriptive case study (Yin, 2003) because the purpose of this study was to understand 7th graders' knowledge construction, problem-solving, meaning-making processes in class by focusing on one case (a Web-enhanced learning environment for 7th graders) and by providing rich descriptions of the case (Merriam, 2002). The case, which in this study is the entire classroom context—what the researcher calls a Web-enhanced learning environment where students solve scientific problems with one of the WISE projects in groups—was selected due to the uniqueness of the classroom setting (Merriam, 1998; Stake, 1995). The technology-enhanced, project-based class in a middle school is located in a suburban area of the Southeastern United States. In this class, this case study was conducted with eleven 7th grade middle school students, who used the "Ocean Stewards" project from WISE in the spring of 2004. The unit of analysis was the individual student. Eleven students whose parents agreed to their participation in this study were selected using convenient sampling.

A wide range of data from multiple sources has been collected (a) to yield rich descriptions of students' cognitive development and the strategies they used to solve problems in Web-based learning environments, and (b) to triangulate the data analysis processes. Data sources include individual interviews with the participants as the major source of data, participants' electronic notes saved in WISE database, PowerPoint files collaboratively created by students, and the researcher's field notes generated from daily observations.

Individual interviews of approximately twenty minutes in length were conducted on the last day of the project. During the three-week activity, the researcher visited and observed the classes. Prior to coming to the project-based class, the researcher had some understanding about the class because she had conducted a preliminary case study with 8th graders in the same class in the Fall of 2003. Data were analyzed using constant comparative data analysis (Glaser & Strauss, 1967). The specific procedures for data analysis include: (1) coding all the data collected from one interview, (2) revising the written codes by examining the field notes and artifacts, generated by participants for triangulation, (3) generating tentative categories and sub-categories based on the revised codes, (4) repeating the same procedures from 1 to 3 for the second interview, the third interview, and the rest of interview transcripts, and (5) finalizing the categories and sub-categories by re-naming or re-locating them.

Findings

Six categories capture the factors shaping the interactions between 7th graders and the inquiry tool in classroom. Each category and sub-category was supported by quotes from individual interviews, field notes, and/or students' artifacts.

Prior Experience and Interest

Most participants reported that they use computers and the World Wide Web at least twice a week to check email, to chat with friends, to play online games, and sometimes to find information for their homework. For the 7th graders, who selected this technology-rich, project-based course, creating Flash animations and movies and preparing PowerPoint for their presentations with computers was not something they had to *learn* but something they could really enjoy and have fun with. In addition to their prior experience and interests in computers, the students' own interest in scientific topics and inquiry processes influenced their interactions with Web-based inquiry tools. Prior experience and interest in using computers and exploring scientific topics motivated students to find problems related to their own lives and to investigate the problems with the WISE projects. When they selected one expedition among three choices (Archeological Findings, Loggerhead Sea Turtle Tagging, and Recreational Fishing and Sport Diving), most participants chose a topic in which they were particularly interested. In her electronic notes, Amy said that "We believe this expedition is important because we want to find out more about sea turtles and we would like to help them from becoming extinct" indicating her prior interest in sea turtles and her recognition of the value of the topic.

Problem-Solving Skills

The participants employed a wide range of different problem-solving skills as they explored scientific problems with Web-based inquiry tools. The researcher classified five different types of problem-solving patterns primarily from the observations: "Right"-answerer, trial and error students, negotiator, reasoner, and inquirer. Right-answerer is a student who tries to find *the* "correct" answer in their investigation. Trial and error students surf a great deal of information without much thinking about their positions or without developing their own ideas on the topic. They may come across useful findings but their procedures and strategies are difficult to transfer to other contexts for further problem solving. Negotiators are students who continuously check their answers and compare their findings and problem-solving processes to those of other people or resources. These students can be good reasoners and inquirers if they constantly construct their own thinking and find further problems to investigate. Reasoners monitor and diagnose their thinking and learning processes. They tend to think deeply about scientific topics and flexibly correct their opinions on them. In contrast to trial and error students, they keenly examine the problems and try to avoid making the same mistakes in further investigations.

Inquirers are not only good reasoners but also good communicators who have a great deal of internal motivation to explore scientific problems. Paul was a good inquirer; he was very motivated to learn about how scientists work in the real world, influenced by his father who knows a lot about marine biology and his brother who is a computer programmer. Paul mentioned that some day he wanted to implement his research proposal titled "What Kind of Fish Live on Gray's Reef at the Surface during the Summer?" In addition, he proposed to continue the WISE project in this class next semester because he felt that he needed more time and effort to deeply understand and explore the topic through hands-on activities.

Most students in this case were negotiators; they were capable of checking their answers and communicating with peers and the teacher to find better ways to solve problems. However, most of the students were unlikely to develop their own explanations and critically reflect on their thinking process.

Design of Tools

The participants stated that the WISE project assisted them to investigate scientific issues by providing guided tasks and meaningful problems. Regarding the design of tools, four sub-categories were found: structured inquiry tasks, authentic problems, hands-on activities, and note-taking features.

Structured inquiry tasks. This Web-enhanced learning environment was designed as a student-centered but scaffolded context in three ways: (1) the WISE project was incorporated into students' own open-ended task, which was writing an expedition proposal in a group, (2) the WISE project provided five major activities[8] that students could inquire about, and (3) the students kept online journals and wrote notes in WISE so that they were able to use them in the process of creating the proposal. The structured activities helped students focus on their investigation and think further about issues associated with the National Marine Sanctuary. Participants pointed out that the WISE activities and notes assisted them to keep their records and to reflect on their progress.

Authentic problems. The Ocean Stewards project incorporated problems relevant to middle school students' interest into the activity where students selected one expedition among three. Most participants wrote and told me that they chose the topic that sounded interesting and important to them. Christine, who wanted to become an archeologist, chose to learn more about "Archeological Findings" and searched for research proposals that archeologists wrote. Dave wrote in his note that he chose this particular topic of Archeological Findings because "we [his group] thought it was very interesting and that we could get more knowledge on marine sanctuaries." In addition, Bob explained that he liked this project because he felt he was doing a real project like a scientist. He stated, "because we've got to do research stuff. You are doing actually like… It's almost like a real thing. You have to do research and put presentations and show we are gonna get funded. So that was pretty cool." The three selections for expedition presented in Ocean Stewards and the authentic nature of the open-ended project helped the students become motivated to explore further issues related to each selection.

Hands-on activities. Some participants pointed out that the text in the WISE project, Ocean Stewards, was too long for them to read through. Sue stated, "I didn't like reading all the

[8] 1. What are National Marine Sanctuaries? 2. Visit Our National Marine Sanctuaries 3. Marine Expeditions 4. Expeditions in Your Sanctuary 5. Planning the Expedition

information because there were like so many stages that I went back…" Bonnie also mentioned, "You have to read all these pages. And I don't like reading" but "I like making stuff here." Rather reading the lengthy text, some participants emphasized the importance of hands-on activity that could have been included in this project. Paul said he likes hands-on activities because "when I learn new stuff, I would rather do it than having someone tell me how to do it." The participants actively constructed their own thinking not while reading the online text but while putting ideas together for expedition proposals in PowerPoint.

Note-taking features. Interestingly, most participants stated that one of the favorite parts in this case (Web-enhanced learning environment) was typing directly on their computers not using notebooks. Their responses indicate that some of the basic features in cognitive tools, such as notes, can reduce students' cognitive overload and help them focus on higher-order thinking skills. The way that the inquiry tools are designed encompasses various issues such as questions of what kinds of problems are represented, how guidance is provided and what kind of interface is supported. The findings of this case study revealed that, for 7th graders' problem solving in WELEs, inquiry tools should support structured, yet authentic tasks.

Peer Engagement

Most participants indicated that it was more productive to work with friends in a group because they were able to learn about different perspectives from other group members, which they couldn't do when working alone. At the beginning of this project, the teacher encouraged the students to work together and the students were able to choose one or two peers that they wanted to work with. Working in a group was not a requirement but most of the students collaborated with one or two other students. They were expected to answer the questions presented in WISE individually; however, they worked together on developing the expedition proposal and putting ideas together on PowerPoint. Sue, who worked with Bonnie, said in individual interviews that they were able to learn different perspectives from each other. Bonnie also told me “I liked working in the group because they [other group members] have different ideas.”

Not only within their own group but also across the groups, the students were able to communicate and share ideas about criteria for evaluating other groups’ work through “Chat Rooms.” The chat Room was embedded in the WISE program and the students freely posted their thoughts either directly related to the topic or not. In addition, on the last day the students looked through other expedition proposals developed in PowerPoint format to decide whether they were going to fund research or not. Students had the opportunity to present their work to their peers and the teacher and to justify their expedition plans. Through these multiple-levels of collaboration, the students were deeply engaged in this inquiry learning environment.

Facilitator’s Expertise

In this case study looking at a technology-rich class, the researcher found six crucial roles that the teacher played in the WELE from her observation: teachers as designers, teachers as problem-solvers, teachers as context analysts, teachers as coaches, teachers as evaluators, and teachers as community members.As a designer, the teacher was capable of understanding WISE and modifying one of the projects to suit her class. Also, she was cognizant of students’ problem solving processes such as how students would approach each expedition and she was willing to tackle with any technical problems that emerged. As a context analyst, she understood students’ needs, interests, and capabilities and reflected them in her daily lesson plans. For example, once she realized that the lengthy text in WISE was not useful for her students, she decided to cut the text down for the next class she taught. As a coach, the teacher demonstrated how to use Student

Journals when needed and asked further questions facilitating students' critical thinking such as "why do you think this topic is important?" As an evaluator, she was able to point out the problems that she had with WISE and suggest how to improve the Ocean Steward project. As a community member, she was willing to share her experience not only with the researcher, but also with the community of teachers and the WISE team.

Nature of Curriculum

This learning environment (case) was very unique because the students did not have to take standardized tests and classroom projects were not limited to a predetermined curriculum. Several salient characteristics of this learning environment include (1) student-centeredness (students select a sub-topic that they want to investigate), (2) students' ownership over their learning pace (about 90% of the class period is assigned to individual or group work and students are responsible for making progress in their projects), and (3) opportunities to learn new computer tools so that students can create their own artifacts.

Discussion

The findings indicate that 7^{th} graders' problem solving in WELEs requires various factors to be taken into account regarding students' prior experience, collaboration, design of tools, teachers' roles, and the nature of curriculum. Based on the findings from this case, the researcher proposes a pedagogical model in which teaching and learning practices with cognitive tools can be grounded (Figure 5). The National Research Council (2000) identified two different types of inquiry as ways for solving problems in science: full and partial inquiry. When teachers plan full inquiry activities (NRC, 2000) in class, students take more control and ownership over their learning than they do partial inquiry activities (NRC, 2000). More specific scaffolding is provided by cognitive tools and teachers when students do partial inquiry in WELEs. As the findings indicate, tools that promote inquiry should encompass authentic problems and hands-on activities and should provide guided assistance due to the challenges that students face such as a lack of prior experience and problem-solving skills.

This case study explored what factors shape interaction between 7th graders problem solving processes and inquiry tools in a WELE. Further research is needed (a) to link students' problem solving processes with the affordances of the WWW, (b) to examine a balance between exploratory and scaffolded learning activities with cognitive tools, (c) to provide in-depth analysis of classroom-based implementation using design research (Brown, 1992; Collins, 1999) and developmental research (Lijnse, 1995), and (d) to analyze how teachers' beliefs and attitudes influence students' problem solving processes with cognitive tools.

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APPENDIX B.

DATA COLLECTION MATERIALS

(STUDENT SURVEYS AND PROJECT HANDOUTS)

Project Handout—Project Scoring

Wolves in Your Backyard

Project Scoring

This project is worth a total of 500 points. You will be scored as follows:

1. **Pretest – 50 points**
   You will be scored on the completeness of your answers. There are no right or wrong answers on the Pretest.
2. **WISE questions – 100 points**
   You will type in answers to questions that are part of the WISE process. Your teacher will be able to read your responses and comment on them by going online. There are 13 questions that are worth 6 points each, and two food chain models that are worth 11 points each.
3. **Brochure Requirements worksheet – 100 points**
   As you are planning your brochure, you will need to answer the questions on the worksheet.
4. **Brochure – 100 points**
   You will receive a list of requirements about the brochure. Points will be deducted as follows:
   - Missing title – deduct 5 points
   - No indication of brochure topic – deduct 5 points
   - Grammar or spelling errors – deduct 1 point per error
   - Missing/irrelevant/poor quality images –deduct 5 points per image
   - Font unreadable – deduct 5 points
   - Missing information from list – deduct 10 points per item
5. **Discussion – 100 points**
   At the end of the project, you will be participating in an online discussion about wolves. You must make at least 5 productive contributions to this discussion in order to earn all 100 points.
6. **Posttest – 50 points**
   You will be scored on the completeness of your answers. There are no right or wrong answers on the Posttest.

Project Handout—Brochure Requirement

Wolves in Your Backyard

Brochure Requirements

Pretend now that you live in an area that wolves also live in. Every year, tourists visit your town to view and photograph wildlife. Wolves are one of the most popular animals among the tourists, and your town depends on money from tourists to keep the economy strong. Farming and ranching are also important to your town's economy, and recently, several cattle and a pet dog have been killed by wolves.

Local lawmakers must make some quick decisions about the wolves in your area, and being a concerned citizen, you would like to inform the lawmakers as to what the best plan is. You plan to share your ideas in a brochure you create using Microsoft Publisher.

Please answer the following questions before constructing your brochure.

1. Which of the following points of view do you agree with the most?
    ____ all wolves should be removed in order to keep people, livestock, and pets safe
    ____ all wolves should be allowed to live freely in order to restore natural order to our area
    ____ somewhere in between these two viewpoints

2. Please give three reasons for your answer to question #1. These reasons should come from what you've learned during this project.

3. In your opinion, how are wolves more important to the economy?
    ____ by hunting, which provides pelts and helps protect expensive livestock
    ____ by being available for photography and viewing by tourists

4. Please give two reasons for your answer to question #3. These reasons should come from what you've learned during this project.

5. In your opinion, is zone management (wolves are protected in some zones but not others) a good solution for the wolves in your area? **Please explain your answer with evidence from the project.**

6. In your opinion, which hunting method is the best solution for the wolves in your area?
    ____ anyone with a wolf hunting license can kill wolves during wolf season
    ____ state officials kill wolves that have caused problems
    ____ landowners kill wolves that threaten livestock on their own property
    ____ no wolves should be killed

7. Please give two reasons for your answer to question #6. These reasons should come from what you've learned during this project.

Please be sure you have answered all of the above questions BEFORE starting your brochure!

Brochure requirements

- ☺ It must have a title.
- ☺ The cover must indicate what the brochure is about.
- ☺ It must be free of grammar and spelling errors.
- ☺ It must contain at least 6 relevant, good quality (not blurry) images.
- ☺ The font color and style must be readable against the background.
- ☺ It must contain the following information. **This information should come from the WISE project!**
  1. Background information on wolves
  2. Your point of view on wolves in general (see question #1 above)
  3. Detailed evidence supporting your viewpoint (question #2 above)
  4. Why you do not agree with the other viewpoints from question #1.
  5. How wolves affect the economy (question #3 above) with explanation (question #4). Be sure to include the opposing viewpoint and why you disagree with it.
  6. What zone management is and why it is or is not a good solution for the wolves in your area (question #5)
  7. The hunting method that would be best for your area (question #6) with explanation (question #7). Be sure to include information on the other methods and why you disagree with them.
  8. A summary of the information in the brochure with a clearly defined solution for the wolves in your area.

To get started on Microsoft Publisher

1. Open up Publisher
2. At the Start Page, choose Publications for Print
3. From the menu on the left, choose Brochures
4. Select a brochure design from the main window
5. Use the same skills you learned when building a web page

Pre-WISE Survey for Students

Wolves in Your Backyard
Survey about your experience with computers!

1. What's your name? __________________

2. What class are you in?
    ____ Class 6A
    ____ Class 6B

3. Why did you select this class among other electives? Please explain below

*Please select one choice for each question.

Very Low	*Low*	*Average*	*High*	*Very High*
1	*2*	*3*	*4*	*5*

4. What was your level of interest in this class before taking it?
1 *2* *3* *4* *5*

5. What is your level of interest in this class now?
1 *2* *3* *4* *5*

6. What is your level of interest in science?
1 *2* *3* *4* *5*

7. What is your level of interest in technologies, computers, and the Internet?
1 *2* *3* *4* *5*

8. What is your level of interest in wolves?
1 *2* *3* *4* *5*

9. How often do you use computers at home?
    _______ About everyday
    _______ About four to six times a week
    _______ About two or three times a week
    _______ About once a week
    _______ About twice or three times a month
    _______ About once a month

10. What do you use computers for at home?

11. How often do you use computers at school?
    _______ About everyday
    _______ About four to six times a week
    _______ About two or three times a week
    _______ About once a week

12. What do you use computers for at school? ___________________________

13. Please indicate the software that you are able to use (mark the checkboxes).

- ❑ Microsoft Word
- ❑ Microsoft PowerPoint
- ❑ Microsoft Publisher
- ❑ Apple Keynote
- ❑ Apple iMovie
- ❑ Web Browsers (Explorer, Netscape, or Safari)
- ❑ Macromedia Flash
- ❑ Macromedia Dreamweaver
- ❑ Adobe Photoshop
- ❑ Others ______________________ (Please write down the name of software here)

14. Where do you get the most help when you work on your project in this class?

_______ From friends
_______ From teacher
_______ From computer or Web sites
_______ All of the above
_______ Other ______________________ (Please write down the source of help)

15. Please write down your personal opinions on the following concepts.

I think doing research means…

For example…

I think scientific investigation is…

For example..

I think problem-solving is…

For example…

Pre-test from the Project "Wolves in Your Backyard"

Wolves in Your Backyard

1. When dealing with populations of wolves I think we should...
   Check one:
   A: provide complete protection for wolves.
   B: eliminate all wolves.
   C: protect only those in Alaska
   D: eliminate wolves where there are farm animals.
   E: develop a plan to manage the population.

Explain your choice.
I chose ____ because ...

2. One problem with allowing wolves in an area near people is that wolves often attack humans.
   Check one:
   A: True
   B: False

Explain your choice.
I think it is a _____ statement because ...

3. If we eliminate all wolves it will allow a greater variety of other species of animals to survive.
   Check one:
   A: True
   B: False

Explain your choice.
I think the statement is _____ because ...

4. Introducing wolves into an area like Yellowstone National Park will have an effect on birds even though wolves do not prey on birds.

Check one:

A: True

B: False

Explain your choice..
Having wolves in an area will ...

5. In Minnesota wolves kill about 40,000 deer each year. Do you think it would be good to eliminate the wolves so this does not happen?

Check one:

A: Yes

B: No

C: It depends

Explain your choice.
I think it would ....

6. Should hunting of wolves be allowed?

Check one:

A: Yes

B: No

C: It depends

Explain your choice.
I believe that hunting ...

APPENDIX C.

INERVIEW PROTOCOLS

Questions for pre-interview

Research Questions	***Purpose of Questions***	***Question items***
1. How do middle school students identify, explore, and solve scientific problems in a Web-enhanced learning environment? 2. How do they use different types of scaffolding (peer, teacher, and technology-enhanced) during their problem solving, inquiry processes?	To find out… Their experience in class	- Tell me about your experience with the WISE project so far. - What did you like the most? Why? - What did you like the least? Why? - How do technologies and computers help you to learn?
	Problem-solving strategies	- What kind of problems did you find and solve in this class? - How did you do that?
	Different types of scaffolding	- Where did you get help when you worked with the problems that you described?
	Research experience in scientific topics	- Tell me about "your" definition of research. - Tell me about "your" experience in research. - What do you think science is? - What kind of scientific problems do you solve at home or at school?
3. What factors influence middle school students' inquiry in the Web-enhanced learning environment?	Opportunities	- What helped you solve problems in class?
	Challenges	- Did you have any difficulty in this class? - What kind of difficulty did you have in this class? - Did you solve the problems? Or How did you solve the problem?

Questions for mid-study interview

Research Questions	***Purpose of Questions***	***Question items***
1. How do middle school students identify, explore, and solve scientific problems in a Web-enhanced learning environment? 2. How do they use different types of scaffolding (peer, teacher, and technology-enhanced) during their problem solving, inquiry processes?	To find out… Their experience in class	- Tell me about your experience in the last science class. - What did you like the most in the classroom activities? Why? - What did you like the least in the classroom activities? Why? - How do technologies and computers help you to learn?
	Problem-solving strategies	- Tell me about what you did and learned from the last class. - What kind of problems did you find and solve in this class? - How did you do that?
	Different types of scaffolding	- Where did you get help when you work with the problems that you described?
	Research experience in scientific topics	- Tell me about “your” definition of research - Tell me about “your” experience in research
3. What factors influence middle school students’ inquiry in the Web-enhanced learning environment?	Opportunities	- What helped you solve problems in class?
	Challenges	- Did you have any difficulty in this class? - What kind of difficulty did you have in this class? - Did you solve the problems? Or how did you solve the problem?

Questions for post-interview

Research Questions	***Purpose of Questions***	***Question items***
1. How do middle school students identify, explore, and solve scientific problems in a Web-enhanced learning environment? 2. How do they use different types of scaffolding (peer, teacher, and technology-enhanced) during their problem solving, inquiry processes?	To find out… Their experience in class	- Tell me about your experience in the last science class. - What did you like the most in the classroom activities? Why? - What did you like the least in the classroom activities? Why? - How do technologies and computers help you to learn? - What made you feel most confident in the science class? - Would you like to recommend this type of activity to your friends?
	Problem-solving strategies	- Tell me about what you did and learned from the last class. - What kind of problems did you find and solve in this class? - How did you do that?
	Different types of scaffolding	- Where did you get help when you worked with the problems that you described?
	Research experience in scientific topics	- Tell me about “your” definition of research. - Tell me about “your” experience in research.
3. What factors influence middle school students’ inquiry in the Web-enhanced learning environment?	Opportunities	- What helped you solve problems in class?
	Challenges	- Did you have any difficulty in this class? - What kind of difficulty did you have in this class? - Did you solve the problems? Or how did you solve the problem?

APPENDIX D.

SAMPLE FIELD NOTES

Date	Wed, March 9, 2005 (Class B—Mon, Wed, Fri) 12:15-1:35 pm	
Project Day	WISE Day 1 Pre-Survey on technology and problem solving (copy available) Pre-test on wolves (copy available)	
Major activities of the day	- Students took the survey on technology and problem solving that I designed - Students took the pretest on wolves (printed version) designed by WISE - Students registered in WISE to get their user name and password for log-in - Elizabeth demonstrated how to use WISE system and major features embedded (Notes, Amanda, Activities) - Students started working on the project—many of them worked on Activity 1	Data sources - My observation field notes - Post test on Internet Research Skills and Website Design - Pre-survey on technology and problem solving - Pre-test on wolves

Time	***Student group/name***	***Issue***	***Data sources***	***Consistent evidence***	***Quotes***
12:25pm	Pre-survey on technology and problem-solving		Pre-survey	Interviews (Pre-WISE)	
12:35pm	Pre-test on Wolves	Students' concern about their answers Some less interested in wolves	Pre-test	Interviews (Pre-WISE)	
12:55pm	Elizabeth's introduction to WISE (demonstration)	Students quickly learn about the new system	Videotape		

This group is very quiet compared to the 6A group yesterday. Once Elizabeth demonstrated some critical features of WISE (activities, Notes, Index), they immediately started working with this project. They say this is so cool because they don't have to write down their answers but type their thoughts. In Activity 1, students read the background information about wolves to answer the question of what do you know about the wolves. Most of them said they don't know much about wolves when they were told to take pre-test on wolves and worried about their poor answers. After taking pre-test and reading some background information, they got an idea of where to start to explore this topic.

Activity 2—Food web: they added more factors and drew relation among them. It seems they need more information about each factor such as what deer can eat?

APPENDIX E.

EXAMPLE DATA ANALYSIS OF SELECTED STUDENTS

Individual student's problem solving patterns organized into three parts for each student:

- Concept on research, problem-solving, and scientific investigation
- Selected Notes
- Focus on project activities, problem-solving strategies, and scaffolds used
- Online brochure (final artifact) created by individual student

This section is arranged according to the following the participants' list:

- Jamie (Quiet inquirer)
- Leslie (Quiet inquirer)
- Natalie (Quiet inquirer group)
- Jade (Communicative inquirer)
- Paige (Communicative inquirer)
- Justin (Self-contained reasoner)
- Ethan (Self-contained reasoner)
- Jen (Peer-supporting reasoner)
- Allison (Peer-supporting reasoner)
- John (Peer-supporting reasoner)
- Sydney (Prompt negotiator)
- Ashley (Prompt negotiator)
- Anthony (Prompt negotiator)
- Timothy (Steady negotiator)
- Zachary (Steady negotiator)
- Hailey (Steady negotiator)
- Kimberly (Steady negotiator)

- Steven (Unfocused trial and error student)
- Kevin (Unfocused trial and error student)

Quiet Inquirer—Jamie

Concept on research, problem-solving, science and subject matter

Concept	***Definition***	***Characteristics***	***Excerpts***
Research	Finding information about a subject	• Information finding • Information based	To find information about a subject; if you research chocolate you find information about it "I think research is pretty much finding out about a subject and then normally reporting about it. Like it's telling what we found out."
Problem-solving	Solving a problem	• Critical thinking	Solving a problem; with one of the cubes figure out how to align the boxes so they will all be one color. "I think it's pretty much solving a problem and finding out what or how something works or why it is or why it's like that."
Scientific investigation	Finding out information and discovering how it works	• Discovery • Information/observation-based	To find out information about something scientific, and normally discover how it works; if you research wolves you find out how the pack functions together and body structure as well as kinds of wolves

Concept	***Position (Changed)***	***Excerpts***
Populations of wolves	<u>*Pre-test*</u> • Provide complete protection for wolves	"If we eliminate all wolves, it will have a terrible effect on the food chain because the wolves' prey will grow and soon devour all the plants and the prey will die of starvation"
	<u>*Post-test*</u> • Develop a plan to manage the population	"If we completely protect the wolves, they would likely get an even worse reputation than they do now, but if we completely eliminate the wolves, their prey will damage forests out due to overpolulation"

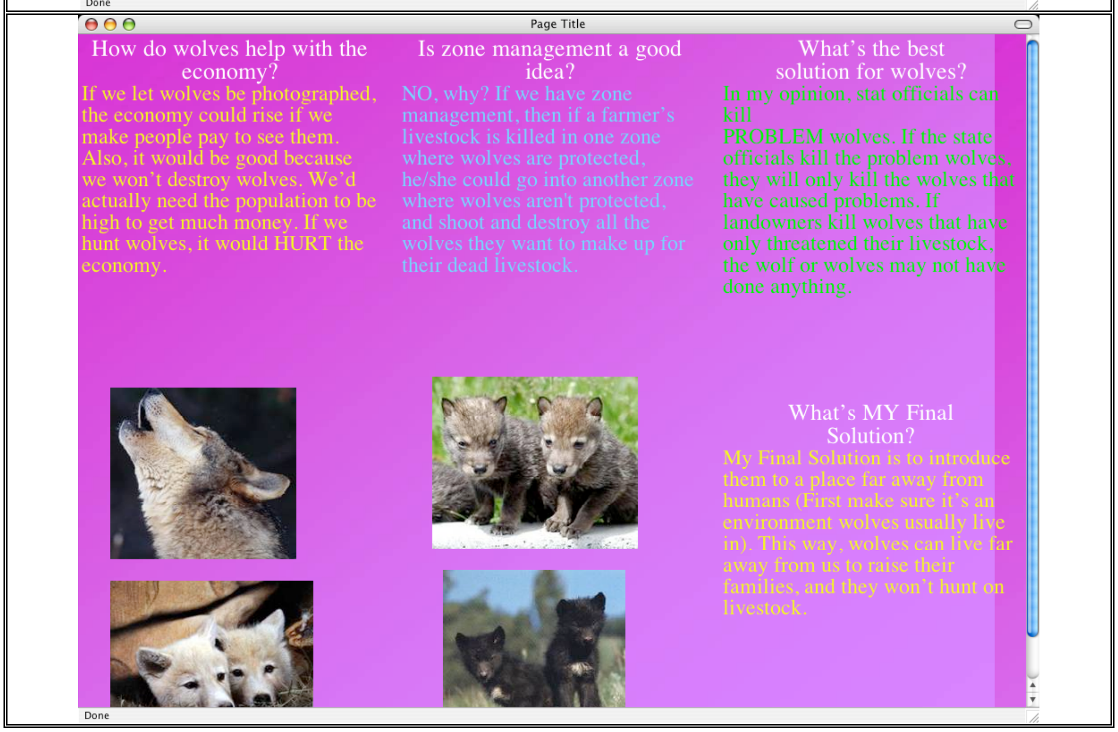
Jamie (Quiet Inquirer) continued—Selected Notes

Topics	***Excerpts***
Wolf Biology	***What do you already know about wolves?*** "Wolves have been hunted nearly to extinction, they have an order of who eats first(called a 'pecking order'), the alpha male and alpha female are normally the only wolves that mate." ***Some things that surprised us were:*** "There has never been an attack by a healthy wild wolf on a human in the United States, about two thirds of wolves die before their first birthday, wolves can eat up to 20% of their body weight at one time, and wolves only eat about every 4-7 days in the wild."
Wolf Controversies	***Do you think wolves should be allowed to live undisturbed in the wilderness near you? Why or why not?*** "I think we should develop a plan to manage the population because... If we totally eliminate the population, the population of animals they hunt will go up, causing the vegatation the prey eat to be destroyed, causing the prey to die. However, if we completely protect the wolves, they could become even greater pests to people than they are now because if they flourish, they could eat all the prey around them and look to farmer's sheep for food. We need to find a way to not eliminate the wolves, but not give them a worse reputation than they have now." ***Do you think either side is right - the farmers or the environmentalists? Why?*** **"**We think the farmers and environmentalists both are right because…As the farmers said, the wolves are eating their livestock, but at the same time I believe they are wrong because the environment could suffer if we completely destroy the wolves. We need to find a way to manage the population without destroying the population or making them unafraid of us."
Management Options	***What did you like about the Minnesota plan?*** "Minnesota wants to make the wolf population grow to a healthy level." ***What did you dislike about the Minnesota plan?*** "Once they grow to a healthy level, they won't be as protected."

Jamie (Quiet Inquirer) continued—Project activities and strategies

Project Activities	***Strategies Used***	***Excerpts***
<u>*Identification (Average)*</u> • Wolf biology (Problem context) • Writing Notes	• Interest in topic • Prior knowledge about topic	"I like learning about the wolves because they're my favorite animal." "I think what helped me was my actually liking this because as I think I told you before, wolves are my favorite animal and I like wolves. And I liked reading about them." "I didn't really think I learned that much because I already knew a lot about wolves because in earlier years, like in elementary school, I actually checked out fiction books about wolves. So, I pretty much found out everything that it said on the website."
<u>*Exploration (High)*</u> • Food chain (Predators and preys) • Writing Notes	• Revisit evidence and Notes • Convenient use of the web/computers	"I like the notes because then you can always look back at them and not have to deal with all this paper and things." "I think you have a lot more things you can do on a computer than you can on paper. And it's a lot easier because if you're doing it by hand it'll take a lot longer to do what you're trying to do than if you were to do it on computer."
<u>*Reconstruction (High)*</u> • Creating brochure • Wolf biology (Evidence) • Reading Notes	• Creative design	"I think I liked making the brochure the most. [because] because I like to type and I like to design things and use colors and stuff and we did a lot of that."
<u>*Presentation/ Communication (Low)*</u> • Chat room	• Personal preference (individual reflection) • Learning style	"Sometimes I like them. Sometimes I didn't. like, I don't always like sharing my answers because I'm the kind of person that likes to keep all my feelings in and not share them. It's weird. I … yeah. So, it really depended on the question. And, as I said before, if I was having a good day or not."
<u>*Reflection/ Negotiation (High)*</u> • Change in the plan	• Evidence-based • Multiple perspectives (farmers and environmentalists) • Revising her opinions • Supporting evidence	"Because I went from thinking that they should be totally protected to somehow managing them. Because I found out that if they were totally protected they could actually get a worse reputation than they had now. So, that would be bad. And then people might actually go ahead and kill them all. And that, of course, bad." "I kind of already had an opinion where I felt like we should completely protect them. But then I read that if we do completely protect them, they might get a worse reputation than they do now. So, I read more and even though I do think it's not always good for wolves to eat livestock in that problem wolves maybe might need to be dealt with. Like eliminated those wolves. But, I read more information about them and I kind of evolved my opinion."

Jamie (Quiet Inquirer) continued—Artifact construction (online brochure)



Quiet Inquirer—Leslie

Concept on research, problem-solving, science and subject matter

Concept	*Definition*	*Characteristics*	*Excerpts*
Research	Looking for information to answer question	• External driven • Answer questions • Information based	Looking for an answer to a question on the Internet or in a book: looking up certain facts to an animal or something “Research is when you’re given a topic and you need to look for information about that topic on certain websites. And you need to answer certain questions about that topic.”
Problem-solving	Thinking of solutions to problems	• Independent processes • Solution-oriented • “Think-through” process • Everyday activities	Thinking of solutions to problems with your own head: trying to figure out how to play games where everyone will be happy. Like each person wants to play a different game, and you play each for a certain amount of time “Problem solving … I think that it is when you’re given a question or problem and you need … and it’s something that you need to think through and figure out the solution, too, without using, maybe the internet or something. [without using] the internet or computer. Just trying to figure it out with your head and maybe working it out and doing a process of elimination when you’re trying to figure it out.” “Problem solving, well, maybe it’s something that you have to do everyday, such as if you’re playing with your friends and you’re trying to agree on a game, where one person wants to play soccer, and one person wants to play baseball or something like that. Then you can think of something where you can play both and, so have fun with it. Like, play one for a certain amount of time and then play the other for a certain amount of time. And just trying to think through things where it would make sense and you don’t have to fight about it.”
Scientific investigation	Looking for scientific information	• Information finding • Utilizing resources	Looking for scientific information either in a book or on a computer: looking up information for one of the planets on the Internet

Concept	*Position (Changed)*	*Excerpts*
Populations of wolves	<u>*Pre-test*</u> • Provide complete protection	“The U.S. uses wolf fur for clothing and stuff and they aren’t dangerous”
	<u>*Post-test*</u> • Develop a plan to manage the population	“If we completely eliminate or protect wolves, then they might become an ever bigger problem with killing other animals or we won’t have any of the fur that we could sell to get money”

Leslie (Quiet Inquirer) continued—Selected Notes

Topics	***Excerpts***
Wolf Biology	***What do you already know about wolves?*** "Wolves were hunted almost to extinction, they live in some of the same places with people, and why do people think they are dangerous?" ***Some things that surprised us were:*** "In the U.S., there has never been an attack on a human from a wolf. Also, about two-thirds of wolves don't live up to their first birthday. They can eat up to 20% of their body weight and have an extremely strong jaw."
Wolf Controversies	***Do you think wolves should be allowed to live undisturbed in the wilderness near you? Why or why not?*** "I think wolves in our area should be protected because wolves kill and eat some of the pests that bother humans. Also, we get them for fur and I don't know, but some people might like the meat. They also eat some of the animals that we kill for food so we are doing the same as them" ***Do you think either side is right - the farmers or the environmentalists? Why?*** "Both are right because wolves need to be free and should live if the wolves died, then people would have some trouble and some animals would be in danger. They are harmless and kill some of the pests we want to get rid of."
Management Options	***What did you like about the Minnesota plan?*** "I liked that Minnesota wanted the wolf population to get to a healthy level and let them live in peace." ***What did you dislike about the Minnesota plan?*** "I didn't like that the status would change at the goal. I want it to be when the wolf population exceeds the goal."

Leslie (Quiet Inquirer) continued—Project activities and strategies

Project Activities	***Strategies Used***	***Excerpts***
<u>*Identification (Average)*</u> • Wolf biology (Problem context) • Writing Notes	• Curiosity • Surprising evidence • Preference for reading • Peer support	"Wolves were hunted almost to extinction, they live in some of the same places with people, and why do people think they are dangerous?" "In the U.S., there has never been an attack on a human from a wolf. Also, about two-thirds of wolves don't live up to their first birthday. They can eat up to 20% of their body weight and have an extremely strong jaw." "Basically, just reading what we had to read about them and then also Jamie told me a little bit about them because she loves wolves."
<u>*Exploration (High)*</u> • Food chain (Predators and preys) • Writing Notes	• Interest in different position • Peer support (conceptual and procedural help) • Confidence from finding more information	"… I don't really know what's going to happen because it said … because some people say that they want them killed and then some people say they want them protected. I just want to see what's going to happen." "She (Jamie) helped me with understanding some of the questions and she also helped me when we were building the food chain how it kind of some things that would help and some things that ate also the wolves ate. She helped me with a lot of stuff." "Yes, I looked at WISE and I did food my chain and then I looked at it some more and found more information about it. And then I revised my food chain and I felt much better about the second one because I knew more about … because I felt more confident."
<u>*Reconstruction (High)*</u> • Creating brochure • Wolf biology (Evidence) • Reading Notes	• Confronting conflicts • Multiple perspectives • Seeking clarification for the task requirement • Rationale-oriented • Creative design with computer	"Well, I just thought about everything that the WISE and everybody told me and I thought that the best solution would be for wolves being protected but if they become a problem then the wolves that were the problem should be killed because you need to keep wolves happy where they can be living. And out in the wild. But we also need to keep people happy because they killed the livestock. And I think everyone should just be happy." "I didn't understand how are you supposed to do the brochure and what to put in it and then now I understand a lot more. I asked Miss Adams and she told me and now it seems easy." "I think I liked making the brochure the most. Because I got to tell my own opinion on things and I just like making things on the computer and I just like to create things. And make them look really good. And I like to use lots of pictures." "Yes, because it is just a lot easier on the computer and when it's easier I can focus more. And I'm not a very good artist. So, I like doing stuff on the computer because it looks better and I feel better about it and I know I did a better job on the computer."

Presentation/ Communication (Average) • Chat room	• Expressing own opinion • Listening to different opinions	"Yes, it was fun because I talk to people on the Internet a lot and also I learned other people's opinions. And I got to just say whatever I wanted and I like just figuring out all the different opinions and telling my opinion on it. I like to speak my opinion a lot."
Reflection/ Negotiation (High) • Using evidence • Peer discussion	• Answering to peer questions • Evidence (information)-based • Change in the plan • "Considering all possibility and choosing the best one" • Learning about other opinions and thinking why	"I think it was because before, if someone had asked me if I liked wolves, I would have said completely eliminate them because I think they are bad animals. But after this, I realized that they are good animals and I would like to have them released in Stone Mountain. And I would like to have them managed so they can still live. I have a whole different opinion on wolves now than I did before we did this project." "Yes, whenever, I tell my opinion, I just don't say, this is what I want to do. I tell people why we should do that, so maybe they'll think through it and think, hey, maybe this is better than just completely eliminating them. So, maybe I can get more people to agree with me and maybe that will happen." "I just really thought about everything and I thought about the different opinions and thought about why this one would be better than this answer and I just really thought through it and said, maybe this better than this because it seems more logical. Or it just seems better for everybody. I try to just think through it and see all the possibilities and choose the best one." Yes, I learned why people wanted to completely protect them or completely eliminate them. And I also learned why some people just wanted to manage them and they wanted a _____ for the wolf population. And if it came to that then they would kill some of them off and let it grow back. And I learned about everybody's opinion and why it should be like that. And it really made you think which one is better. And that really helped a lot with when I was trying to figure out my own opinion."

Leslie (Quiet Inquirer) continued—Artifact construction (online brochure)

Page Title

My Point of View!!!

I think that wolves should be protected, but if they become a problem, then the wolves that are a problem are killed. This is my Opinion because wolves and people should be happy. Also, people get fur from the wolves and can make a lot of money from that. The last thing is wolves are not bad animals. They are more afraid of us as we are of them. The only way they would attack us is if we messed with them.

Zone Management!!!

Zone management is where in some areas, the wolves will be completely protected, not allowed, or allowed to be hunted with a limit to how many are hunted. I think zone management is good because then everybody will be happy. The wolves will be able to live in peace and be able to be free, the farmers will be happy because it saves their livestock, and the U.S. will be able to get more money because they can hunt wolves and sell the fur without making the wolves become endangered.

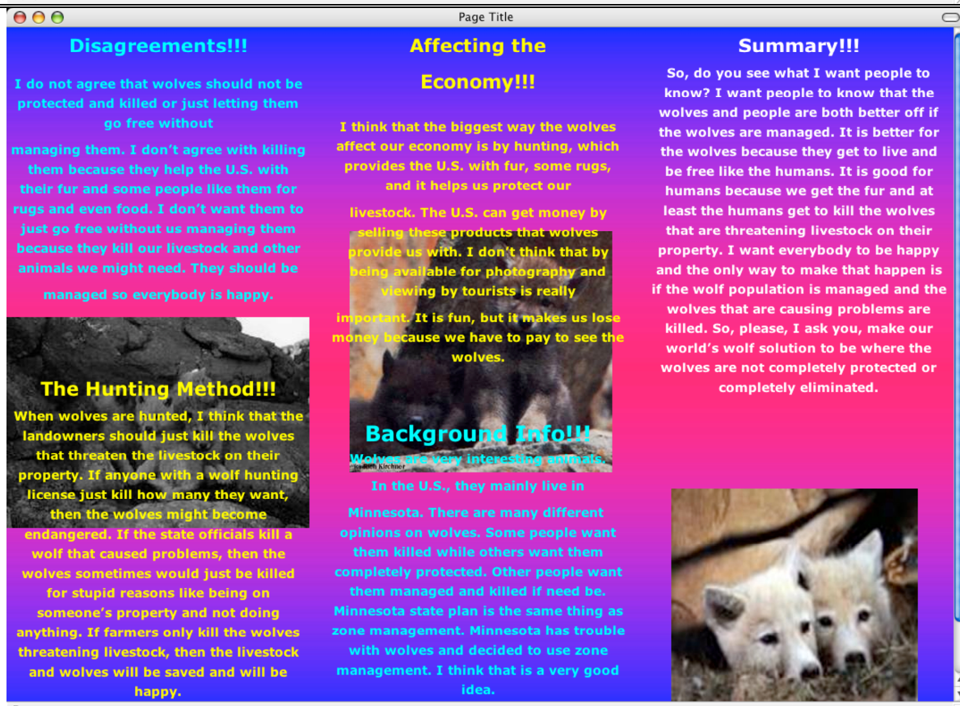
Product of [redacted] Industries. Chicago, Illinois, 2005.

Wolves, Protected, Killed, or Both?

By: [redacted]

Should wolves be protected, killed, or between protected and killed? Find out in this brochure.

Done



Page Title

Disagreements!!!

I do not agree that wolves should not be protected and killed or just letting them go free without

managing them. I don't agree with killing them because they help the U.S. with their fur and some people like them for rugs and even food. I don't want them to just go free without us managing them because they kill our livestock and other animals we might need. They should be

managed so everybody is happy.

The Hunting Method!!!

When wolves are hunted, I think that the landowners should just kill the wolves that threaten the livestock on their property. If anyone with a wolf hunting license just kill how many they want, then the wolves might become endangered. If the state officials kill a wolf that caused problems, then the wolves sometimes would just be killed for stupid reasons like being on someone's property and not doing anything. If farmers only kill the wolves threatening livestock, then the livestock and wolves will be saved and will be happy.

Affecting the Economy!!!

I think that the biggest way the wolves affect our economy is by hunting, which provides the U.S. with fur, some rugs, and it helps us protect our

livestock. The U.S. can get money by selling these products that wolves provide us with. I don't think that by being available for photography and viewing by tourists is really

important. It is fun, but it makes us lose money because we have to pay to see the wolves.

Background Info!!!

Wolves are very interesting animals.

In the U.S., they mainly live in

Minnesota. There are many different opinions on wolves. Some people want them killed while others want them completely protected. Other people want them managed and killed if need be. Minnesota state plan is the same thing as zone management. Minnesota has trouble with wolves and decided to use zone management. I think that is a very good idea.

Summary!!!

So, do you see what I want people to know? I want people to know that the wolves and people are both better off if the wolves are managed. It is better for the wolves because they get to live and be free like the humans. It is good for humans because we get the fur and at least the humans get to kill the wolves that are threatening livestock on their property. I want everybody to be happy and the only way to make that happen is if the wolf population is managed and the wolves that are causing problems are killed. So, please, I ask you, make our world's wolf solution to be where the wolves are not completely protected or completely eliminated.

Done

Quiet Inquirer Group—Natalie

Concept on research, problem-solving, science and subject matter

Concept	*Definition*	*Characteristics*	*Excerpts*
Research	Getting into depth with information and learning more about it	• "Getting into depth" • Learning process • Utilizing resources • Picking a topic and narrowing it down • Representing results in your own words	Getting into depth with information and learning more about it; if you wanted to know more about Benjamin Franklin, you would find resources like books and internet with pics and info "When you really want to know about something and you're determined to find it and information that is important about things and maybe not important … but just information about something." "You first pick a topic and you narrow it down so you know exactly what you're researching so you're not all over the place when you're doing it. And you figure out what you're going to research on like a book or a website. And you go and you find the topic in that book or website and you basically just write down what you find and put it in your own words and really learn about it and then present it to people."
Problem-solving	Finding an answer to a problem through research	• Research process to find an answer	When you have a problem and you research and strive to find the answer; if you were working out a math problem "When something's … when a problem has come up and you research and you figure out the answer till you know for sure that that's the answer…. You really get in depth to it. You don't want to just find one thing in [inaudible] that's the problem answer. You've really got to research it and, you know."
Scientific investigation	Investigating clues to answer a question	• Systemic process to link clues and answer • Starting with something that puzzles you	When a problem or question has occurred then you research it and investigate clues and information leading you to the answer; if you wanted to be a paleontologist, you would research and read up on the bone that you found that puzzles you

Concept	*Position (Changed)*	*Excerpts*
Populations of wolves	<u>*Pre-test*</u> • Not completed <u>*Post-test*</u> • Develop a plan to mange the population	 "The wolves need to be manages and protected"

Natalie (Quiet Inquirer Group) continued—Selected Notes

Topics	***Excerpts***
Wolf Biology	***What do you already know about wolves?*** "I know that the wolves are endangered and need help. I also know that they are related to dogs (of course) and that many die before their first birthday." ***Some things that surprised us were:*** "that they weigh alot and that they don't eat humans- also that they can live 8 to 10 years in the wild."
Wolf Controversies	***Do you think wolves should be allowed to live undisturbed in the wilderness near you? Why or why not?*** "I think wolves in our area should be protected. Because any wolf in any area is still as important as the wolves in any other area" ***Do you think either side is right - the farmers or the environmentalists? Why?*** "We think the environmentalists because the wolves are very."
Management Options	***What did you like about the Minnesota plan?*** "managing the population." ***What did you dislike about the Minnesota plan?*** "no wolf should be hurt."

Natalie (Quiet Inquirer Group) continued—Project activities and strategies

Project Activities	***Strategies Used***	***Excerpts***
<u>*Identification (Average)*</u> • Wolf biology (Problem context) • Writing Notes	• Reading about interesting information • Learning about a new topic as a novice	"I've liked reading all the information about wolves. It's kind of sad how they're all extinct. Not all of them but how they're getting extinct and they're in danger." "I liked doing the notes because I learned so much about wolves. I'm not a big wolf expert, so it was really interesting."
<u>*Exploration (High)*</u> • Food chain (Predators and preys) • Writing Notes	• Reading about interesting information • Using activity structures embedded in the tool	"There's a lot of reading a lot of information that came up. There's a lot that we did the chat rooms and stuff like that. So, there was a lot of information on WISE that you could learn." "I did (liked) WISE because it was really clear and they really told you a lot about wolves. Stuff that people just don't know. It's pretty cool." "I disliked having to read all that much because there was a lot of papers to read. But I love learning all the information. They had really good information." "I think it was very easy because everything was very organized so you knew .. you were reading. It just didn't jump from one thing to another. And they had it to where you could take notes easily. And you could remember the stuff. I liked that the way that they organized it a lot."
<u>*Reconstruction (High)*</u> • Creating brochure • Wolf biology (Evidence) • Reading Notes	• Creative design with computer • Preference for hands-on project activities • Flexibility and creativity	"It's much neater if you type stuff. And you do the colors on there and you find the pictures. Doing it by hand. I'm not a very good drawer and my handwriting's not the best so it looks much better with the other." "There's much more information on the computer. There's much more pictures and colors and stuff like that than you can actually do by hand." "This class is more hands on. You get to do a lot of different things or with … where you make stuff and you do stuff. You're not really … they're not really focused on .. I don't know. It's a bit more fun. It's more … you get to interact more with this stuff and do more stuff instead of read a textbook all day." "I think that the projects that we do in here are much more fun. They focus on your creativity and they focus on what you learned. And you get to have a lot more fun with your projects. You've got much more range on what you can do with your projects. It's cool."
<u>*Presentation/ Communication (Average)*</u> • Chat room	• Recognizing the limitation of shallow level discussion	"Chat room. That … it wasn't, I mean, you had to think but it wasn't much detail or stuff like that. Just feedback and stuff."
<u>*Reflection/ Negotiation (Average)*</u>	• Different perspectives	"Sometimes you only look at them one way and then you look at something somebody else's way and you learn so much more from them than you could have imagined. It's pretty cool."

Natalie (Quiet Inquirer Group) continued—Artifact construction (online brochure)

Communicative Inquirer—Jade

Concept on research, problem-solving, science and subject matter

Concept	***Definition***	***Characteristics***	***Excerpts***
Research	Finding information and representing your understanding in your own words	• Information based • Representing your understanding • Likely to be boring unless you are doing an interesting topic	To have a problem or topic and finding info until you have enough to answer your questions or solve your problem; trying to find out who invented white-out "Research is finding information about a certain topic and putting it in your own words, so it's understandable. Well, some researching is hard and some is interesting but a lot of times, it's boring. I don't like research. It takes a long time and after a while, it gets kind of boring. Though, if we're doing an interesting project, it's a different story. Because we get to have fun and stuff. But, you know…"
Problem-solving	Coming up with a solution to a problem encountered	• Solution-oriented	Problem-solving is having a problem and trying to solve it with all that you know; doing a math problem "I don't know. Problem solving is when you're given a problem and I guess, you just have to work on it until you think you have the right answer. I don't know. A problem that I solved was … my TV was broken and it wouldn't go on. It would turn off before it would go … like, after five minutes and then I turned it on and off really quickly and then it started working again."
Scientific investigation	Using science to solve problems	• Problem-based • "Using science"	When you use science to solve a problem; the crime labs when they use DNA

Concept	***Position (Not Changed)***	***Excerpts***
Populations of wolves	<u>*Pre-test*</u> • Develop a plan to manage the population	"If we provide complete protection for wolves, the farm animals might be eaten and we many not have enough meat for everybody to go around"
	<u>*Post-test*</u> • Develop a plan to manage the population	"If there is a plan to manage the population, not all wolves will be hunted to extinction and wolves will be in areas that they want to be in"

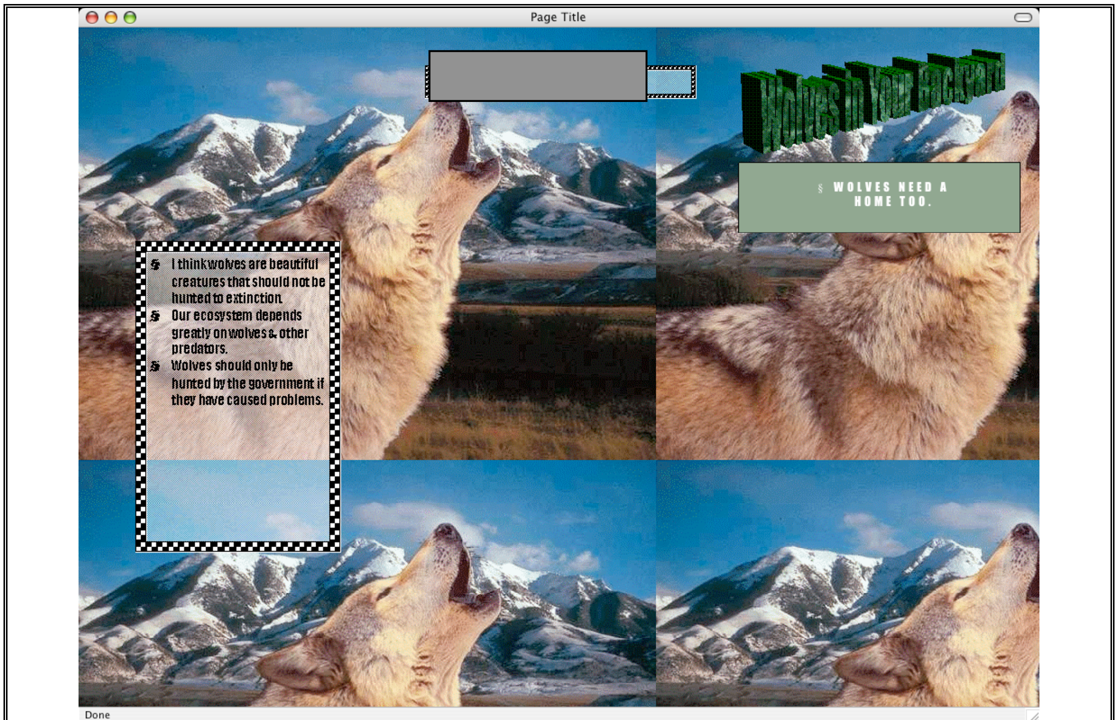
Jade (Communicative Inquirer) continued—Selected Notes

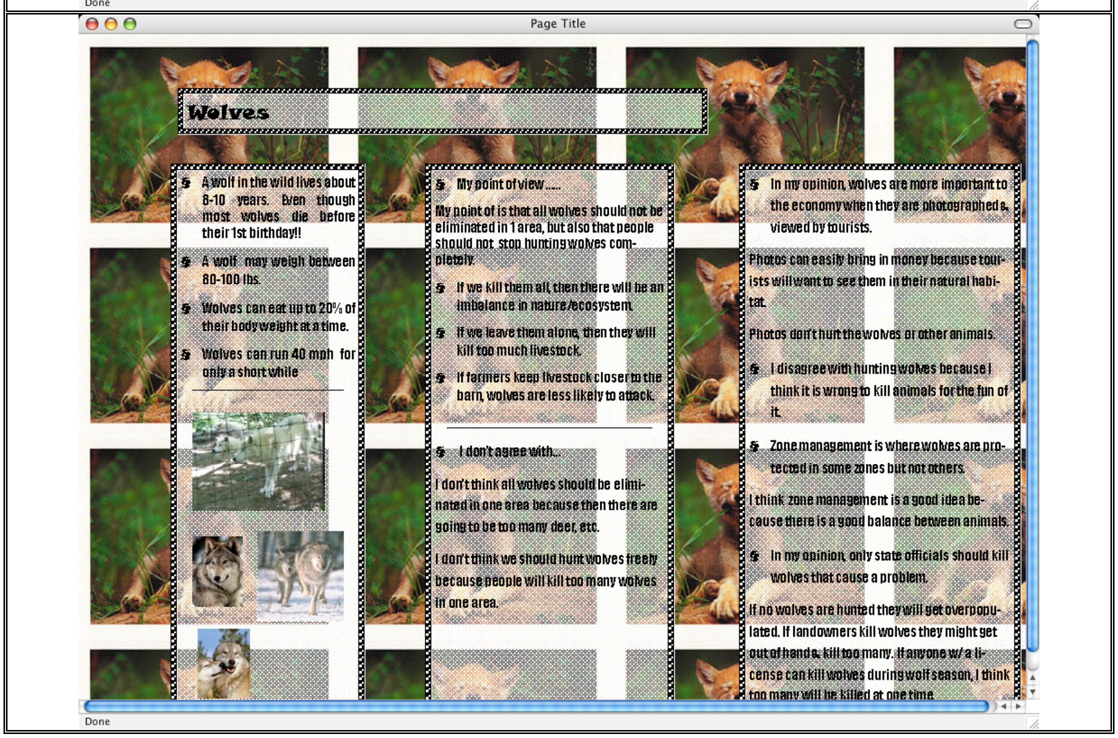
Topics	***Excerpts***
Wolf Biology	***What do you already know about wolves?*** "*wolves live in north american forests & in cold places *wolves were on the endangered species list *nobody can kill wolves anymore" ***Some things that surprised us were:*** "*that they can eat 20% of their own body weight *that a wolves jaw is 5 times stronger than an adult human's jaw. *that they can run at 40mph for only short periods of time."
Wolf Controversies	***Do you think wolves should be allowed to live undisturbed in the wilderness near you? Why or why not?*** "I think wolves in our area should be protected. Because if we eliminate them, we are just as bad as we think they are. Everything should live in peace & harmony even if some sheep get killed because they need to eat too." ***Do you think either side is right - the farmers or the environmentalists? Why?*** "I think the both are right because the wolves that are close to the farmers's farms might eat their animals. We also shouldn't completely eliminate them from 1 area because that might cause an imbalance in the ecosystem."
Management Options	***What did you like about the Minnesota plan?*** "it helps the out by managing their population." ***What did you dislike about the Minnesota plan?*** "they will only watch the wolves after delisting them for 5 years.."

Jade (Communicative Inquirer) continued—Project activities and strategies

Project Activities	***Strategies Used***	***Excerpts***
Identification (Average) • Wolf biology (Problem context) • Writing Notes	• Utilizing prompts embedded in Notes as a thinking cue and start point	"I like the way there was the activity and the notes. That was kind of cool how the notes were set up. Where it started into a question for you so you didn't have to think about a good start for it. So, I liked that."
Exploration (High) • Food chain (Predators and preys) • Writing Notes	• Figuring out relationship/connecti on among factors	"The most interesting activity so far was the WISE where you got to make the food gram. [oh, this activity] yes, I enjoyed this. [why] I like changing the colors and making it all together and seeing how much it all depends on each other. How one thing depends on everything else. That was really interesting."
	• Connecting different factors	"There was a box that had wolf, that had the word wolf in it and you put the boxes with the wolf connected to it and you put what the animals eat in it. And you connected it all to it and you saw that the wolf eats all those animals. And then the animals eat these plants and then the plants get their energy from the sun .. get their food from the sun. that was kind of fun. I liked seeing it connect."
	• Revisiting Notes	"So .. and I learned it by reading some things and then taking notes on it on WISE. And I think that was kind of fun because it was an interesting way to do it. Because you could go back and look at it and you could do that."
Reconstruction (High) • Creating brochure • Wolf biology (Evidence) • Reading Notes	• Checking task requirements • Revisiting Notes for brochure contents	"It's going well. I have gotten … I am busy getting information to put on the background of the wolves. I have found backgrounds for the brochure so it'll look cool. And I'm just making sure of all my requirements are … I have all the requirements that I need and that it's done correctly. So, I'm going to be good." "And I think the WISE notes is a good way because you can look back if you wanted to do the brochure, maybe. If you wanted to put some of that on the brochure. And I just kind of thought it was fun."
Presentation/ Communication (High) • Chat room	• Enjoying argument	"If somebody picked a topic, and then you could reply on the topic they chose. And then people could reply to you and you could have a whole conversation arguing about your opinion to their opinion. And I thought that was fun."
Reflection/ Negotiation (Average)	• Feedback and grade from instructor	"Least confident was I didn't understand the questions and I thought I was going to get a bad grade because I thought that the answers that I put were incorrect. But then I saw that they were correct. So, that made me feel better."

Jade (Communicative Inquirer) continued—Artifact construction (online brochure)





Communicative Inquirer—Paige

Concept on research, problem-solving, science and subject matter

Concept	*Definition*	*Characteristics*	*Excerpts*
Research	Looking up information to find answer	• External-driven (questions) • Answer-finding • Real-world problems	When you look up a topic on the computer, in a book, or asking someone; looking in an encyclopedia and researching wolves "Like when you look up … like when you get asked a question and you look up the answer. Like, on the Internet or like a book. Well, we researched stuff like the first few days of class. We researched like stuff on the Tsunami that happened. Like safety procedures and stuff with that. [was it interesting?] Yeah, like the first day we did this thing, if the water went bad, what would you do? Like I didn't know that meant that the big Tsunami was coming, so I said I would save all the fish. So, I'd probably died, so it's good to learn."
Problem-solving	Learning new things by solving problem	• Encountering and solving new problems	When you solve a problem in math, b. when you solve a problem not mathematically; a. 2+2=, b.how can we get people to stop cutting down trees and building stuff "Like, when you solved something that you didn't know. Like maybe a math problem or like anything. Like, if you didn't know how to use the Internet or something like that?"
Scientific investigation	Doing research or experiments	• Same as research • Scientific topic	the same thing as research and/or doing experiments; researching waves then doing wave experiment

Concept	*Position (Not Changed)*	*Excerpts*
Populations of wolves	<u>*Pre-test*</u> • Develop a plan to manage the population	"We don't want people to be able to hunt all of the wolves but they should not overpopulate because that could be a danger to farms"
	<u>*Post-test*</u> • Develop a plan to manage the population	"Wolves deserve to be here but they shouldn't run the world or always be on the brink of extinction"

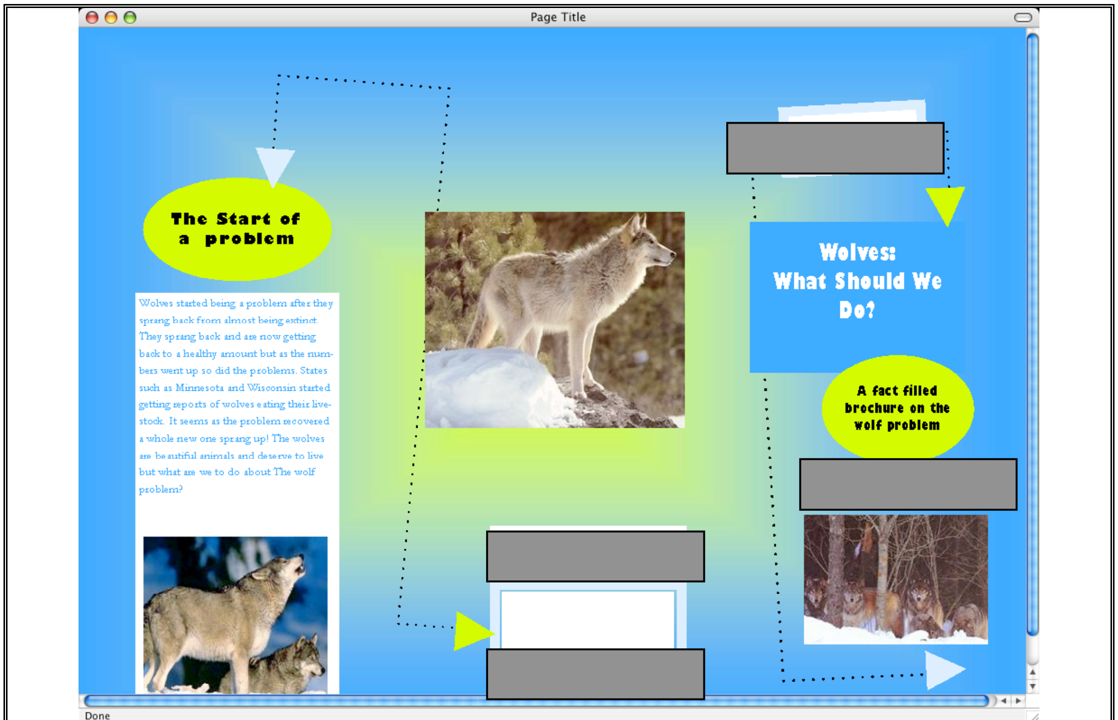
Paige (Communicative Inquirer) continued—Selected Notes

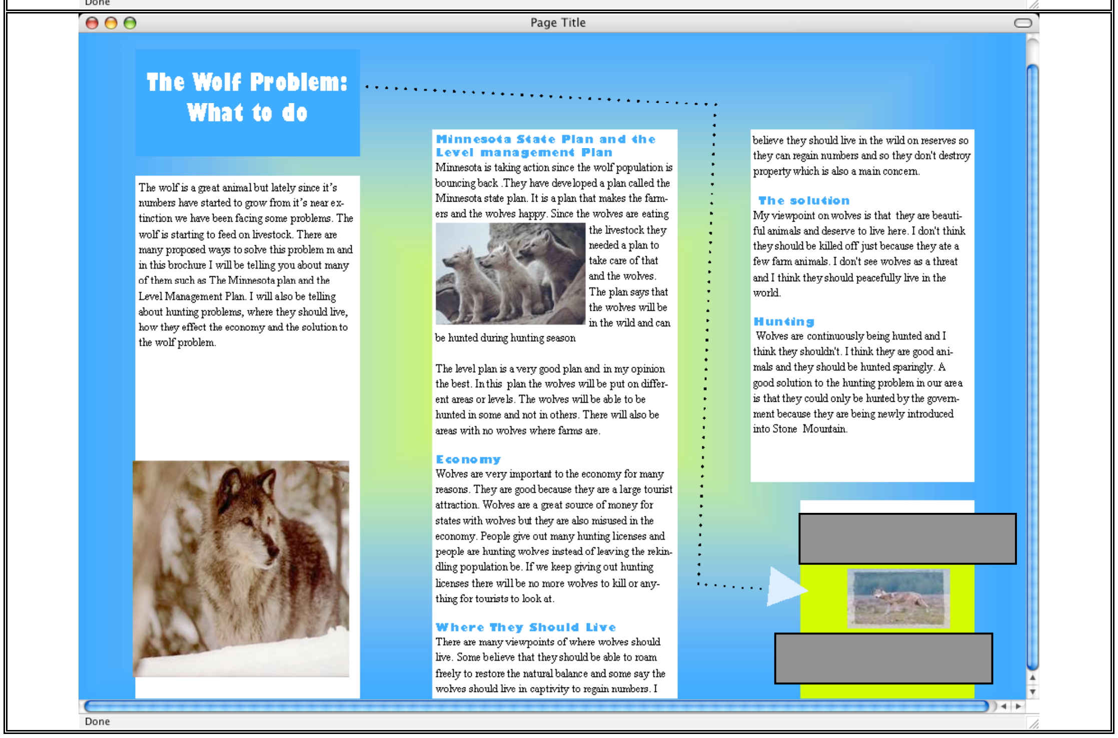
Topics	*Excerpts*
Wolf Biology	***What do you already know about wolves?*** "I know that wolves are a problem that no one really knows the answer to. Wolves are coming in contact with humans more because of the receding forest line. I want to know more about the solution of the wolf problem." ***Some things that surprised us were:*** "I learned that they can eat 20% of their weight thats a lot!!! I was surprised that they had such a strong jaw. I thought it was funny that the gray wolf was many colors other than gray."
Wolf Controversies	***Do you think wolves should be allowed to live undisturbed in the wilderness near you? Why or why not?*** "I think they should be protected a little. Because they are an important part of our world and thy really are beautiful. They are probably like any other animal and they will only mess with you if you do them, unless their unhealthy.." ***Do you think either side is right - the farmers or the environmentalists? Why?*** **"**both are right because...I think that they are both right because I agree with environmentalists that the natural order should be remade but the ranchers do need their animals to survive so it is a hard decision and I don't think everyone will ever be happy."
Management Options	***What did you like about the Minnesota plan?*** "The Minnesota plan seemed like a very effective way to deal with the wolves. I liked the rules about you can keep a few then kill a few with a minimum of the population." ***What did you dislike about the Minnesota plan?*** "the part of how if a wolf is around you you can kill it. I think it has to do something to deserve to be killed. I'm not talking about if it is a foot away from you and foaming at the mouth i'm talking about if it's like 4 yards and just sitting there."

Paige (Communicative Inquirer) continued—Project activities and strategies

Project Activities	***Strategies Used***	***Excerpts***
Identification (Average) • Wolf biology (Problem context) • Writing Notes		
Exploration (High) • Food chain (Predators and preys) • Writing Notes	• Writing based on own thinking and information from WISE	"Well, we had some topics to write about and so I just wrote about what I thought and the information that I had got from WISE."
Reconstruction (High) • Creating brochure • Wolf biology (Evidence) • Reading Notes	• Opinion-oriented • Beyond typing facts	"I like the brochure. Yeah. It was .. it … because you could type what you wanted to type and not just facts. You could have your opinion in there and stuff."
Presentation/ Communication (Average) • Chat room	• Instant communication	"The chat room was cool because it was like .. like you could see what people were writing and what people thought and that was cool because it was like what they were really typing right then. Yeah"
Reflection/ Negotiation (Average)		

Paige (Communicative Inquirer) continued—Artifact construction (online brochure)





Self-contained Reasoner—Justin

Concept on research, problem-solving, science and subject matter

Concept	***Definition***	***Characteristics***	***Excerpts***
Research	Finding out more about what you don't know	• Problem-based (about persons) • Utilizing resources (computer)	Figuring out problems and finding out about a person with a computer; researching Neil Armstrong "Research … research is trying to find something that you haven't learned much about. And usually it's for a class of some sort"
Problem-solving	Figuring out a problem with knowledge	• Problem-based • Knowledge-oriented • Independent process	Figuring out a problem with your own knowledge: If you had 2 apples and ate one, how many are there? "Problem solving is something in math. It's boring and trying to fix something that you messed up on like the computer shut down accidentally and you can't turn it back on. You've got to fix it somehow."
Scientific investigation	N/A	N/A	"?"

Concept	***Position (Changed)***	***Excerpts***
Populations of wolves	*<u>Pre-test</u>* • Eliminate all wolves	"I'm evil (short and to the point)"
	<u>Post-test</u> • Develop a plan to manage the population	"People want to hunt them and tourists want to see and protect them, so it's a balanced situation"

Justin (Self-contained reasoner) continued—Selected Notes

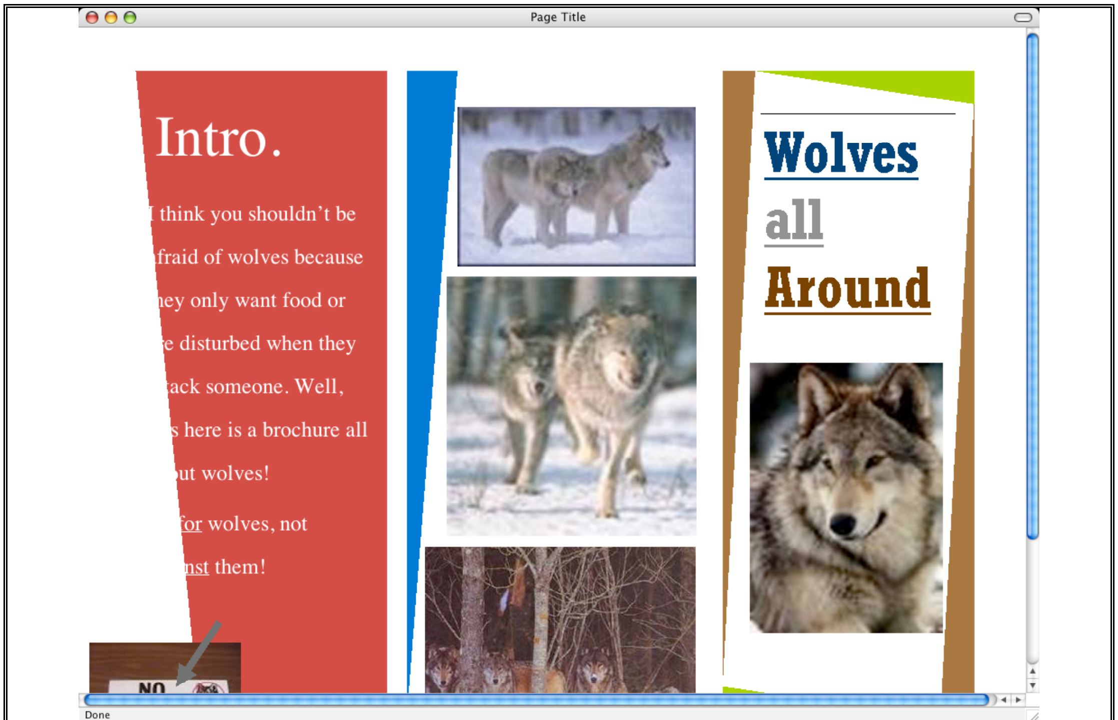
Topics	***Excerpts***
Wolf Biology	***What do you already know about wolves?*** "They mark their territory just like dogs do. They're related to dogs. They travel in packs. They howl to find the rest of their pack." ***Some things that surprised us were:*** "Their jaws are 5 times the strength of ours! Wolves are endangered in most of the world! They can eat up to 20 pounds in only one meal!"
Wolf Controversies	***Do you think wolves should be allowed to live undisturbed in the wilderness near you? Why or why not?*** "I'm glad we don't have wolves in our area because I would always be scared of some hunting me down, but at the same time I would love to have some around. I can't make my mind up!" ***Do you think either side is right - the farmers or the environmentalists? Why?*** "I don't think farmers should be that worried about wolves in their land. They just need to put a fence up and they won't intrude! So don't try and shoot them!"
Management Options	***What did you like about the Minnesota plan?*** "???? It doesn't tell you about it!" ***What did you dislike about the Minnesota plan?*** "???? It doesn't tell you about it!"

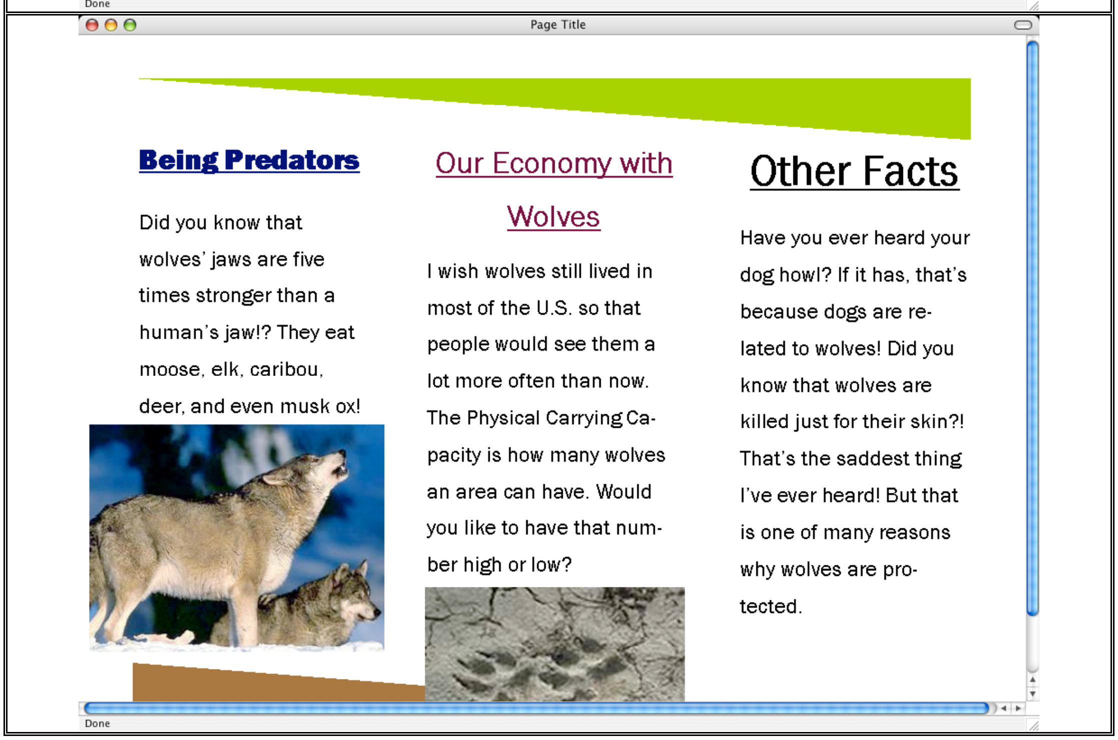
Justin (Self-contained reasoner) continued—Project activities and strategies

Project Activities	***Strategies Used***	***Excerpts***
Identification (Average) • Wolf biology (Problem context) • Writing Notes	• Ownership over selecting research topic • Identifying critical issues	"How you get to pick yourself. Not letting … not like other classes where the teacher picks your partner or picks what you're researching on or something like that. You get to pick everything." "If we kill all the wolves off then basically the whole … then elk … all this stuff that they eat could die off too. Because they kill off the sick and the weak ones, so the sick stay … because if the wolves don't eat them then they could all die off because of disease and stuff."
Exploration (High) • Food chain (Predators and preys) • Writing Notes	• Awareness of limitations in his knowledge about technologies • Personal value for helping others • Answering questions in Notes ("definitely useful, just too many")	"Just because it's not my favorite thing to work with. I mean, I don't know everything about the computer and … I'm not really good at naming all the parts of the computer. Like, I only know the printer, the keyboard and the computer." "Like … well, in scouts I have a lot of friends there and the motto is "Do a good turn daily." [say it again, please] the motto is "Do a good turn daily." In other words help somebody daily. And that helps because everybody is wanting to help you and stuff." "All the notes, I guess. [why] because you have to do notes on every section of reading that you do on the [because the questions are tough or …] because you have to do so many notes. Yeah, they're definitely useful, just too many." "It was good but it might have had too much notes. [too many questions you need to answer] yeah. [too much information too] no. actually, it was good. It's just that it had too many notes."
Reconstruction (High) • Creating brochure • Wolf biology (Evidence) • Reading Notes	• Preference for hands-on design activities • Considering broad/public perspectives	"Probably the brochure about it. Because you actually get to do something other than the notes and reading. And it .. you could do pictures of stuff on wolves and it was cool." "Well, you actually get to type what you feel and notes and brochures. Brochure's telling basically what everybody likes not just you. So, it kind of balances that there."
Presentation/ Communication (Low) • Chat room	• Concerning about discussion off topic	"The chat room was kind of weird because people were getting off topic and .. but I tried to reply and make them get back on topic. Somebody says, hey, what's up? And I go, uh, nothing, but "blah blah blah blah blah" about wolves to get them back on topic."
Reflection/ Negotiation (High) • Change in the plan	• Conceptual change • Evidence-based	"Well, I used to hate wolves but now I see that I .. just because a movie, a scary movie that I shouldn't hate them. And so … now they're pretty cool." "Just that there aren't that many attacks and if there are it's probably because they're hungry or something like that. And they're about to die of starvation and just

	everything about it." "Because now I know that they only live up in Minnesota. They aren't going to hurt me and it's just , they're cool and sort of like sharks. I used to hate them. But now I like them because they were a third grade focus project. And it sort of changes your mind, I guess."

Justin (Self-contained reasoner) continued—Artifact construction (online brochure)





Self-contained Reasoner—Ethan

Concept on research, problem-solving, science and subject matter

Concept	***Definition***	***Characteristics***	***Excerpts***
Research	Finding more about a topic	• Based on a selected topic • Utilizing resources • Variety of topics	Finding out more about a topic "I think research is when you use certain resources to find … to learn more about something. Whether it be your own life, invention, person, anything."
Problem-solving	Using a system of steps to solve a problem	• Systemic process • Procedures • Utilizing resources	Using a system of steps to solve a problem "Problem solving is when .. problem solving for me is basically when you have a certain number of steps and resources to solve a problem"
Scientific investigation	Finding something scientific through an investigation	• Scientific topic • Investigative process	Finding something scientific through an investigation

Concept	***Position (Not Changed)***	***Excerpts***
Populations of wolves	*Pre-test* • Develop a plan to manage the population	"Wolves deserve the human's respect. They kill animals that we don't like. If the population gets out of hand, we do have hunters."
	Post-test • Develop a plan to manage the population	"Not all wolves are near farms. Not all wolves are a threat to humans or other animals. Those wolves deserve to live. If they are a threat, they should be killed or relocated"

Ethan (Self-contained reasoner) continued—Selected Notes

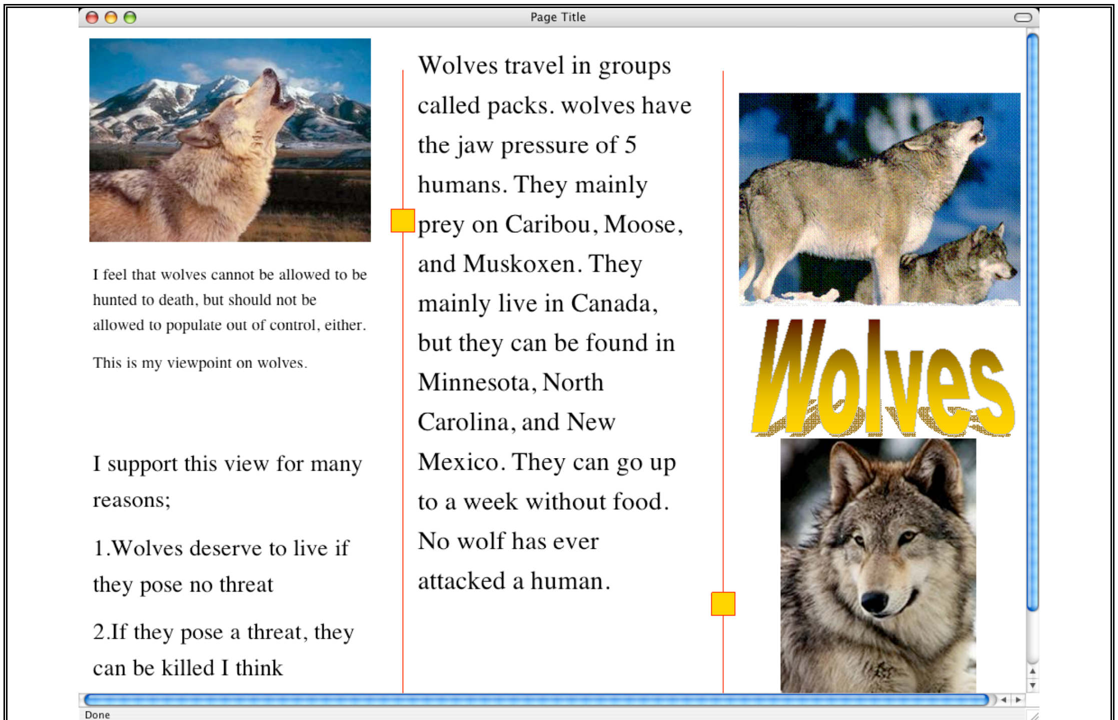
Topics	***Excerpts***
Wolf Biology	***What do you already know about wolves?*** "Wolves travel in groups called packs. Wolves are carnivores, which means they eat meat. Wolves are relatives of dogs." ***Some things that surprised us were:*** "Wolves jaws bite force is 1500 pounds per square inch, 5 times that of a human's jaw. No wolves have ever attacked a human in the United states. Most wolves (2/3 of them) die before they are 1 year old. Wolves are endangered in Georgia (who knew)!"
Wolf Controversies	***Do you think wolves should be allowed to live undisturbed in the wilderness near you? Why or why not?*** Did not answer ***Do you think either side is right - the farmers or the environmentalists? Why?*** **"**I think both groups are correct. Something should be done to protect the livestock, but the wolves deserve to live. After all, the wolves were there first."
Management Options	***What did you like about the Minnesota plan?*** "It would manage the population VERY well." ***What did you dislike about the Minnesota plan?*** "There are chances of the wolves becoming to numerous."

Ethan (Self-contained reasoner) continued—Project activities and strategies

Project Activities	***Strategies Used***	***Excerpts***
Identification (Average) • Wolf biology (Problem context) • Writing Notes		
Exploration (High) • Food chain (Predators and preys) • Writing Notes	• Revisiting Notes and revising them	"Yes, pretty useful [because] because sometimes you might type something and then you want to add something else to it. Sometimes you go back and it's helpful because you can go back to it. Once you go past, it's not over … you can type it again." "I would go back every once in a while and check something because sometimes they wouldn't have it on the sheet I was using. So, I would go back in WISE and look at it. Like what they ate. I would go back in twice at what they ate."
	• WISE as a comprehensive learning context	"yeah. I'd recommend it. If you learn … it's very easy to learn WISE because on some programs, you have to look at some and then you have to look at something else and then you're bouncing all over the internet. But on WISE, it's just one place. It's all in one nice area. I'd recommend it."
Reconstruction (Average) • Creating brochure • Wolf biology (Evidence) • Reading Notes	• Perceived challenge to start off	"One of the interesting things I found was that during the brochure, I kind of had a … whenever I had to do a project, I have problems just starting off. That's the ____ thing. But when I finally started off, it got easier from there."
	• Referring to project guidelines and requirement	"A lot. [a lot] a whole lot [how come] because if I didn't have this sheet it tells you right here. It tells you what you're supposed to have from the brochure. So, you if we didn't have the brochure, I'd have no clue what to put on it." "I figured out the information to put in the brochure by … I looked at the sheet I had to use for the brochure and I looked at certain things and then I looked back at what I had and I thought, I would put that in and that in. I singled out what I was going to put in and I copied that down and used that. Helps in the long run."
	• Revisiting WISE for brochure contents	"So, I just go back and see if I've forgotten something. If I forgotten something, it's here on the sheet. I'll just go back on WISE and look at it."
	• Setting up and following outlines for brochure design	"Basically what I did was, I decided what I wanted to do. I write everything I had to put in it and I just started typing and doing other things. Typing, cutting, pasting. I didn't know how to paste. That happened.
Presentation/ Communication (Low) • Chat room	• Internet connection/speed (slow) • Expressing	"My problem was during the discussion part and during the assignment 6, it took me 10 minutes for it to load. [slow connection?] yes, very slow connection. [all day?] just for one part. Yeah, just the discussion part

	opinions	and for that one part." "Because in the chat room you could really express your feelings toward wolves. Although sometimes you say, I hate wolves, someone might yell at you across the room. But that was the worst. _____ if not, someone's going to run across the room and beat your face in. they might just yell at you. Because at school, they get suspended for that. So, only an idiot would do that."
Reflection/ Negotiation (Average)	• Appreciating different teaching and learning styles	"Yes, they're definitely different. The way they teach is different. The way you go about learning it's different. What you do while learning it's different."

Ethan (Self-contained reasoner) continued—Artifact construction (online brochure)



Page Title

I feel that wolves cannot be allowed to be hunted to death, but should not be allowed to populate out of control, either.

This is my viewpoint on wolves.

I support this view for many reasons;

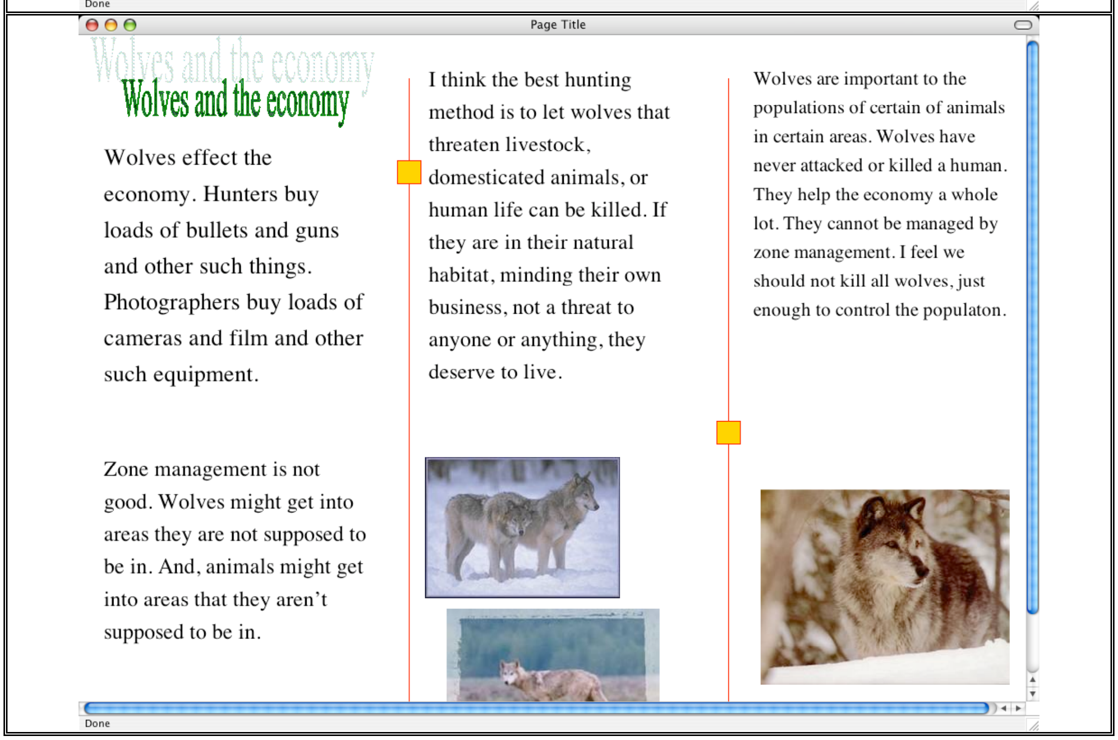
1.Wolves deserve to live if they pose no threat

2.If they pose a threat, they can be killed I think

Wolves travel in groups called packs. wolves have the jaw pressure of 5 humans. They mainly prey on Caribou, Moose, and Muskoxen. They mainly live in Canada, but they can be found in Minnesota, North Carolina, and New Mexico. They can go up to a week without food. No wolf has ever attacked a human.

Wolves

Done



Page Title

Wolves and the economy

Wolves effect the economy. Hunters buy loads of bullets and guns and other such things. Photographers buy loads of cameras and film and other such equipment.

Zone management is not good. Wolves might get into areas they are not supposed to be in. And, animals might get into areas that they aren't supposed to be in.

I think the best hunting method is to let wolves that threaten livestock, domesticated animals, or human life can be killed. If they are in their natural habitat, minding their own business, not a threat to anyone or anything, they deserve to live.

Wolves are important to the populations of certain of animals in certain areas. Wolves have never attacked or killed a human. They help the economy a whole lot. They cannot be managed by zone management. I feel we should not kill all wolves, just enough to control the populaton.

Done

Peer-supporting Reasoner—Jen

Concept on research, problem-solving, science and subject matter

Concept	***Definition***	***Characteristics***	***Excerpts***
Research	Increase of knowledge of a subject	• Increasing knowledge • Novel knowledge	Your knowledge of a subject increases. You are able to find unusual things that you never knew before; you can learn why the pupils of cats are sometimes narrow or sometimes big.
Problem-solving	Finding answer to mathematic problems	• Story-based • Numerical	Using a story to help you find an answer that deals with numbers; If Jack has 3 apples and he eats one how many apples does he have
Scientific investigation	Learning about a certain topic	• Extensive process • Learning process	Learning about everything under just what you see by skimming through something or just looking at the surface; why certain things react the way they do.

Concept	***Position (Changed)***	***Excerpts***
Populations of wolves	<u>*Pre-test*</u> • Provide complete protection for wolves	“Wolves aren’t completely vicious. Sometimes they may just feel threatened, and then they feel that they are forced to attack in order to protect themselves”
	<u>*Post-test*</u> • Develop a plan to manage the population	“We shouldn’t just take them out of all places, kill them, or just let them roam freely wherever they want to. There should be limits”

Selected Notes

Topics	***Excerpts***
Wolf Biology	<u>***What do you already know about wolves?***</u> “I would like to know how long wolves have been on the Earth. I know that wolves were considered an endangered species in 1974, and that wolves were forbidden to be killed.” <u>***Some things that surprised us were:***</u> “Wolves can weigh between 80 to 100 pounds. They can go up to 7 days without eating, and that is why they usually eat about 20% of there body's weight at once.”
Wolf Controversies	<u>***Do you think wolves should be allowed to live undisturbed in the wilderness near you? Why or why not?***</u> “Because...they may prey on other animals, but they have to eat. they don't just kill the sheep for fun.” <u>***Do you think either side is right - the farmers or the environmentalists? Why?***</u> **“**BOTH are right because...in a way they both are right because we need to consider the wolves as living things, but we still have to take control sometimes when they are not doing well.”
Management Options	<u>***What did you like about the Minnesota plan?***</u> “they are not just saying we don’t want wolves, but we are getting too much and we have to do something about it.” <u>***What did you dislike about the Minnesota plan?***</u> “they weren’t very nice to them to start out with.”

Jen (Peer-supporting reasoner) continued—Project activities and strategies

Project Activities	***Strategies Used***	***Excerpts***
<u>*Identification (Average)*</u> • Wolf biology (Problem context) • Writing Notes	• Recognizing difficulties with getting started at the beginning of the project • Recognizing the lack of prior knowledge	"I'm always lost at the beginning when we start the stuff. And that's pretty much the only problem that I have." "I didn't actually learn a lot because I knew few stuff about wolves. But the things I didn't know, such as the zone management, I don't really understand it, but I'm guessing it means such as they would have an area with wolves and some wolves couldn't be hunted because you can't hunt on that premises."
<u>*Exploration (Average)*</u> • Food chain (Predators and preys) • Writing Notes	• Utilizing situated knowledge based on evidence	"Right now I'm doing pretty much the same thing as everyone else. But I'm kind of disgusted by all the stuff that's eaten because I like wolves and I don't eat a lot of animals. I don't eat one kind of animal and that's chicken. And I love wolves. yes. And I hear about how their being held and people don't like them and how people feel threatened by them. But they may actually feel threatened by us so they attack us. So, I'm making a food chain of what I know."
<u>*Reconstruction (Average)*</u> • Creating brochure • Wolf biology (Evidence) • Reading Notes	• Enjoying the use of computer to design brochure • Utilizing requirement sheet as guidance	"So, I liked making the brochure because I love going on the computer. The computer is fun." "I felt it was very easy because you basically had all of what you were supposed to answer due to the worksheet."
<u>*Presentation/ Communication (Average)*</u> • Chat room	• Enjoying chat room discussion • Finding limitations of chat room (focusing on off tasks)	"And I like learning about it in the chat room where everyone was talking about the wolves. It was fun." "The chat room … I talked about wolves. Not many people did. They were like mainly just talking to their friends or if they were talking about wolves, they were just making fun of wolves. It wasn't very nice but when I talked about wolves, it wasn't very informational." "I didn't really want to read all that because some of it I felt that it was useless. None of it I really needed to know. Some of the things .. some of the information about wolves were good but they put sentences in there that really had not much to do with it. And so, it was more of like they were getting off topic."
<u>*Reflection/ Negotiation (High)*</u> • Change in the plan	• Asking for help when confused	"If I didn't understand what they were talking about, I'd ask them, what does this mean? And they'd explain it to me like, she explained the zone management thing. I still don't understand it very well. But I understand it better than I did before. Because I thought it was like .. I thought it was the fact that just all the wolves were together and people could still hunt for it. It's people not hunting on certain premises and they can hunt on the other part."

Jen (Peer-supporting reasoner) continued—Artifact construction (online brochure)

Page Title

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In this brochure you will e able to view different points of views on wolves.

LETS TALK WOLVES!!!!!!!

Done

Page Title

Wolves and the environment.

Wolves are mammals that have been on the Earth for centuries. Wolves are meat eaters that consume deer, moose, sheep, and many other animals that live in our environment. Many people consider wolves to be dangerous predators that attack for no absolute reason. The truth is that wolves mainly attack when they feel threatened. we have to give wolves the chance to roam around without us trailing behind them.

MY VIEW ON WOLVES

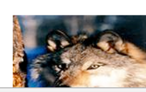
_____I think that wolves should be free to a certain extent. We should set aside a special area for wolves to go about there day.

Wolves DO NOT attack people. They mainly just kill animals to eat. Other animals prey on other animals, but we do not abolish of them all. Many things that people say about wolves aren't true, but they continue to develop a fear.

Wolves are important to the economy for hunting, Which provides pelt and helps protect expensive livestock. I feel this way because pelt helps people stay warm, and livestock should be here so that people can eat. Although in zone management some wolves will be protected because people may no hunt in certain areas, Other

wolves will be hunted and die. Some wolves may die at a very high rate because many people like to hunt wolves, and some people feel that because the wolves have already killed so many animals, They should kill the wolves to protect themselves.

I also think that landowners should be able to kill wolves that threaten livestock on their property because it is like a return. The wolves have killed things on their property.



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Peer-supporting Reasoner—Allison

Concept on research, problem-solving, science and subject matter

Concept	***Definition***	***Characteristics***	***Excerpts***
Research	Process of finding information	• Information finding	Looking up information that is needed for a special topic; Google search looking up things on our birthstone when we did the birthday project "My definition is … the process of finding information."
Problem-solving	Solving a problem in an orderly manner	• Systematic process	I think it means to solve a problem in an orderly manner; putting a playground together "It's the solving of a problem."
Scientific investigation	Conducting experiments	• Experiments • Drawing clusions	Do things scientifically like experiments to come to a conclusion; finding out if a magnet attracts copper

Concept	***Position (Changed)***	***Excerpts***
Populations of wolves	*Pre-test* • Provide complete protection for wolves	"They deserve protection like the pandas do. They are in some places endangered and with other endangered animals we help them."
	Post-test • Develop a plan to manage the population	"If we kill them all, we will be doing what they were doing to the livestock, and it we keep them all, then the count of animals will be off balance."

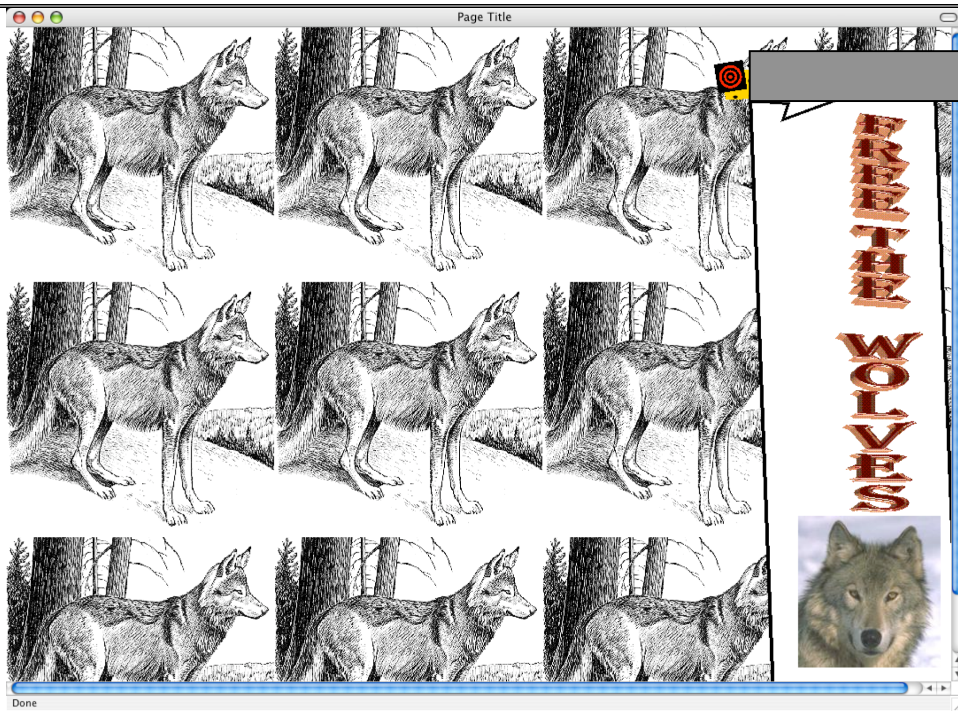
Selected Notes

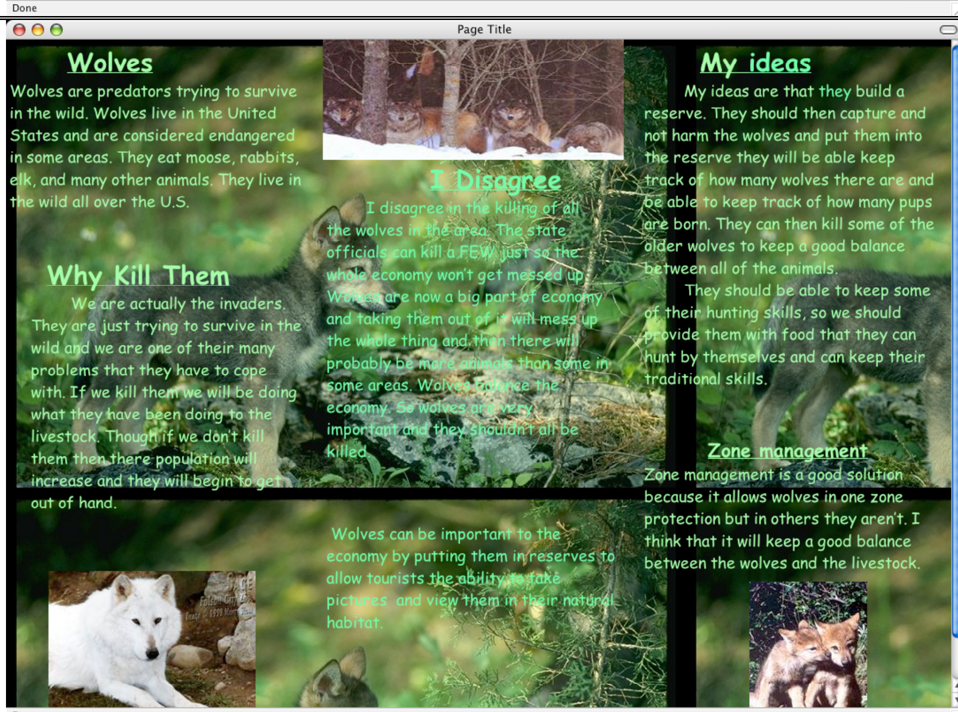
Topics	***Excerpts***
Wolf Biology	***What do you already know about wolves?*** "I would like to know where wolves originated. I would also like to know who there biggest enemy besides humans is. I know that they are en endangered species." ***Some things that surprised us were:*** "I've learned that wolves bite with a 1500 pounds per square inch. They are also almost at a regular status. Wolves can run up to 40 mph. They also live in packs."
Wolf Controversies	***Do you think wolves should be allowed to live undisturbed in the wilderness near you? Why or why not?*** "They should be protected because they are like any other animal trying to survive. We protect the tigers and they are killers to." ***Do you think either side is right - the farmers or the environmentalists? Why?*** "The environmentalists are right because by bringing the wolves back. It restores the natural order of things and they were here before us."
Management Options	***What did you like about the Minnesota plan?*** "It helps the wolves out by managing there population." ***What did you dislike about the Minnesota plan?*** "They will only watch the wolves for five years after delisting them."

Allison (Peer-supporting reasoner) continued—Project activities and strategies

Project Activities	***Strategies Used***	***Excerpts***
Identification (Average) • Wolf biology (Problem context) • Writing Notes	• N/A	
Exploration (High) • Food chain (Predators and preys) • Writing Notes • No revision on the food chain	• Utilizing search engine to create food chain • Recognizing difficulties and challenges with understanding evidence	"I know that deer eat apples because I fed a deer an apple once. Well, you see moose eating grass on movies, so you know that they … and well, I looked it up some of these things on Ask Jeeves, like what do elk eat and all that." "What I didn't like was some of the questions were … had bigger words that I don't really know what they meant. That's basically it."
Reconstruction (High) • Creating brochure • Wolf biology (Evidence) • Reading Notes	• Utilizing WISE information and Notes for brochure design • Feeling confident with brochure design due to available information	"You got to use that information too of what you put your answers down for" "Well, on the wise activity when you had to do the notes, they asked you the question and you had to reply to that. But on the brochure, well, there were requirements but you got to put little extra stuff if you wanted to. I guess so, yeah." "I feel confident I did good on my brochure. [so, what made you feel confident about the brochure?] I had a lot of information."
Presentation/ Communication (Average) • Chat room	• N/A	
Reflection/ Negotiation (Average) • Change in the plan	• N/A	

Allison (Peer-supporting reasoner) continued—Artifact construction (online brochure)





Peer-supporting Reasoner—John

Concept on research, problem-solving, science and subject matter

Concept	*Definition*	*Characteristics*	*Excerpts*
Research	Gathering facts and presenting them	• Information gathering • Information presenting • Interesting	Gathering facts and presenting them; powerpoints "Research is gathering facts and learning about them and then presenting them in an interesting way. Not just study, study, study and learn them."
Problem-solving	Solving a problem	• Showing how to do	Just that. Solving a problem "Pretty much get a problem and solve it. [for example] The hyperlink. I had no idea how to put a hyperlink in. he showed me how. That solved it."
Scientific investigation	Scientific research	• Research	Scientific research; researching science

Concept	*Position (Changed)*	*Excerpts*
Populations of wolves	<u>*Pre-test*</u> • Develop a plan to manage the population	"They are over hunted."
	<u>*Post-test*</u> • Eliminate wolves where there are farm animals	"Because wolves don't harm people, but they do harm crops."

Selected Notes

Topics	*Excerpts*
Wolf Biology	<u>***What do you already know about wolves?***</u> "it is hard to control wolf population. more and more wolves are being killed. scientists are trying to preserve the wolves.." <u>***Some things that surprised us were:***</u> "wolves have 5 times as much jaw power as humans. there are no recorded attacks from a healthy wolf in the U.S.."
Wolf Controversies	<u>***Do you think wolves should be allowed to live undisturbed in the wilderness near you? Why or why not?***</u> "We think wolves in our area should be protected because... they keep a balance in our community. Without wolves, there would be too many other animals." <u>***Do you think either side is right - the farmers or the environmentalists? Why?***</u> "Both are right because... farmers do need their land to farm. However, environmentalists could replenish the population in other areas."
Management Options	<u>***What did you like about the Minnesota plan?***</u> "it was fair to all." <u>***What did you dislike about the Minnesota plan?***</u> "it may not work."

John (Peer-supporting Reasoner) continued—Project activities and strategies

Project Activities	***Strategies Used***	***Excerpts***
Identification (Average) • Wolf biology (Problem context) • Writing Notes	• Conceptual change in wolves based on evidence (wolf biology)	"That wolves really aren't that vicious of creatures. There haven't been any recorded wolf attacks in the United States. That people are so afraid to think wolf and they try to kill it or get away but it's not the case."
Exploration (High) • Food chain (Predators and preys) • Writing Notes	• Utilizing WISE as problem-context and processing tool	"if I forget something I can always go back to look it up again. Make sure that I'm still right on that if I'm like, do they eat muskrats or rats. You can always go back and check that." "You would probably get WISE from google, but you would also get some other wolf projects. But WISE is also a all wolf project. So, you know. That's the main difference. Google, you would get multiple things but WISE is mainly wolves. I do think. I don't know of any other things you can get." "I always had information that I could always go back and refer to and it's not just like a quiz that she gives us. It's always, if you're unsure about something, you can always go back and check, unlike a quiz."
Reconstruction (High) • Creating brochure • Wolf biology (Evidence) • Reading Notes	• Utilizing situated knowledge	"Well, I'm going to put in how really the only wolves that should be killed are the ones that are causing problems to homeowners and their livestock. You know? Because some people just see a wolf in their back yard and go, oh, no, it's going to kill me. And they kill it. But that's not really true. It's probably just looking through your garbage for food or something. Or there's probably a rabbit in your backyard or something. So, it's really just trying to get its own food. It's not going to get you unless it's really hungry."
	• Putting answers to Notes in brochure	"we learned a bunch about wolves and how to answer some questions about it and so … taken that knowledge and put it into the brochure."
	• Motivation	"If you have to do school work at least do something like this. Instead of just reading your textbook and filling out your workbook. You know, it's just a lot more interesting the way that they do it on WISE because you get a little bit information, do a little bit of the work. A little more information, a little more of the work. Rather than just all the information and then all the work. You get bored of both, quickly. But if you're going off and on, you're not as bored. That was a big idea."
Presentation/ Communication (Average) • Chat room	• Feeling free to talk to peers online	"Because you might feel intimidated to talk to somebody upfront but if you're just typing to them, you're not going to care."
Reflection/ Negotiation (Low) • Change in the plan	N/A	

John (Peer-supporting Reasoner) continued—Artifact construction (online brochure)

Prompt Negotiator—Sydney

Concept on research, problem-solving, science and subject matter

Concept	*Definition*	*Characteristics*	*Excerpts*
Research	Finding out more info about a certain topic	• Information-based • Utilizing computers	Finding out more info about a certain topic; wolve research "Research is learning about a certain topic, easier when you use the computer."
Problem-solving	Figuring out the answer of a problem	• Hard working process • Answer-toward • Different ways to solve problems	Working hard to figure out the answer of a problem; math work, problems "It helps you to learn about how you think about things like from your perspective. And like just how to solve problems in different ways."
Scientific investigati on	Learning more about a topic in science	• Learning process • Dealing with a topic in science	Learning more about a topic in science; forensics

Concept	*Position (Changed)*	*Excerpts*
Population s of wolves	*Pre-test* • Provide complete protection for wolves *Post-test* • Develop a plan to manage the population	"Wolves are very special and beautiful creatures and deserve to be protected." "If you had wolves near your home, you would be a little scored, and if you don't have them at all then al the other pop will go up."

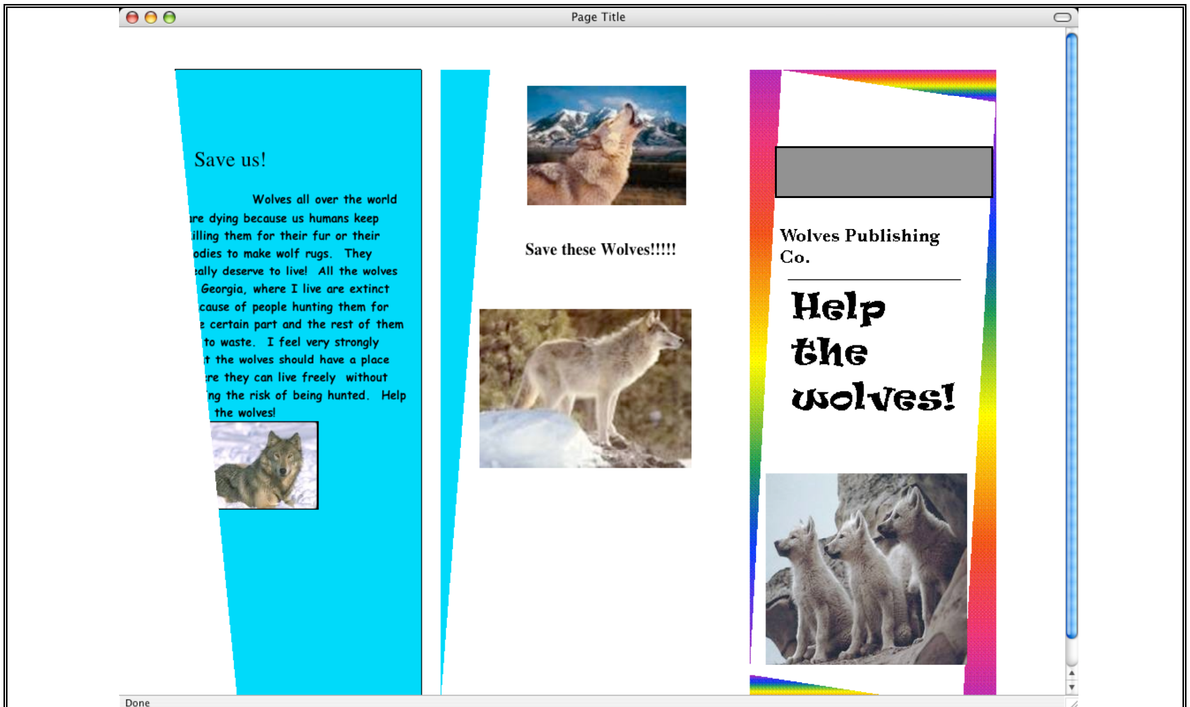
Sydney (Prompt Negotiator) continued—Selected Notes

Topics	*Excerpts*
Wolf Biology	***What do you already know about wolves?*** "I know that wolves live in the same type of environment as human do. Also i no if you don't bother them then they won't bother you. also they don't need to be hunted in the wild because they are endangered and n't deserve to be taken away from their habitat." ***Some things that surprised us were:*** "Most wolves weigh a lot more than i do and some of them don't even live to see their first birthday. And they can eat 20% of their body weight. Also there has never been a wolf attack in the US."
Wolf Controversies	***Do you think wolves should be allowed to live undisturbed in the wilderness near you? Why or why not?*** "i think they should be protected because if you leave them alone then they won't bother you either. and they are really important to the ecosystem and they are very beautiful creatures." ***Do you think either side is right - the farmers or the environmentalists? Why?*** "the farmers are right because...they shouldn't have to deal with the wolves on their farm lands but also we should have another place for them to go."
Management Options	***What did you like about the Minnesota plan?*** "the wolves can't be harmed or anything." ***What did you dislike about the Minnesota plan?*** "i tihnk some shoul be hun ted because they will just keep acumulating or just let them get killed by their natural predators."

Sydney (Prompt Negotiator) continued—Project activities and strategies

Project Activities	***Strategies Used***	***Excerpts***
<u>*Identification (Low)*</u> • Wolf biology (Problem context) • Writing Notes		
<u>*Exploration (Average)*</u> • Food chain (Predators and preys) • Writing Notes	• Using prior knowledge • Asking instructor and peers • Utilizing WISE to express thoughts and type/save answers in it	"[about food chain]" I just kind of thought about it and what they usually would eat. And I asked some of my friends and Miss Adams." "I liked doing the WISE program because it's easy to tell your thoughts and you don't have to like write it all down. Just type it."
<u>*Reconstruction (Average)*</u> • Creating brochure • Wolf biology (Evidence) • Reading Notes	• Didn't like doing research on wolves or telling viewpoint on it • Being proud of herself as fast learner • Wanting to finish the project quickly	"[what did you like the least] Probably just doing all the research. Just kind of like boring but [for example] Well, I couldn't … I don't know. [answering questions] yeah. Like, when we had to tell our viewpoint on it." "Just like a hard working student. I just like to want to get the work done."
<u>*Presentation/ Communication (High)*</u> • Chat room	• Reading other students' opinions on the subject	"That was pretty fun. You got to see how everyone else felt on the subject."
<u>*Reflection/ Negotiation (Low)*</u>		

Sydney (Prompt Negotiator) continued—Artifact construction (online brochure)



Prompt Negotiator—Ashley

Concept on research, problem-solving, science and subject matter

Concept	*Definition*	*Characteristics*	*Excerpts*
Research	Gathering facts from books or websites	• Utilizing books or websites • Facts-gathering	Finding out certain things; the research on the birth months "I think research is like the facts that you learn off of … like, not from a person, but maybe from a book or from a website. It's not something that you know off the top of your head. You have to go learn it from somewhere." "If we didn't have computers, we'd have to go through reading books and finding the books. So, like, reading is okay. But I'd much rather be on the Internet."
Problem-solving	Using what you know to solve a problem	• Based on prior knowledge • Independent process • Overcoming obstacles • Getting what you need	Using what you know to solve a problem; when I was afraid of the softball "I guess problems would be something that you don't like or something that keep … and obstacle. Something that keeps you from what you need or want and solving it would be like finding a way to get rid of the problem to pass the obstacle or get to what you need or want." "Problem solving like outside of school, a problem for me… I play softball, so when I first started, I was afraid of the ball. So, that was an obstacle for me. Now, whenever I get out there, I put my glove right in front of my face, so I want it to come to my face. So, I don't worry about being afraid of it."
Scientific investigation	Investigate something scientific	• Similar to problem solving or research	Investigate something scientific; problem solving, research

Concept	*Position (Changed)*	*Excerpts*
Populations of wolves	<u>*Pre-test*</u> • Provide complete protection for wolves	"They are beautiful animals and deserve to live."
	<u>*Post-test*</u> • Develop a plan to manage the population	"Many people have problems with wolves, but others need wolves. For example, a wolf might attack someone's livestock but they're also good for photos and tourism.

Ashley (Prompt Negotiator) continued—Selected Notes

Topics	***Excerpts***
Wolf Biology	***What do you already know about wolves?*** "I know that wolves are often hunted, and a long time ago, they were hunted almost into extinction. In 1974 they were put onto they endangered species list. Now, they are much closer to fine living." ***Some things that surprised us were:*** "two thirds of the wolves die before their first birthday, because of disease, starvation, or an accident during hunting. A wolf can weigh between 80-100 pounds, and can eat 20% of it's body weight."
Wolf Controversies	***Do you think wolves should be allowed to live undisturbed in the wilderness near you? Why or why not?*** "We think wolves in our area should be protected because these are beautiful animals, and it's not a game to kill living animals, and they've never done anything to us, and if someone doesn't like what they eat, then that person needs to keep those things safer." ***Do you think either side is right - the farmers or the environmentalists? Why?*** "i think that they're both right, because the wolves are important, but too many could ruin our way of eating. If the wolves eat all our farm animals, then we won't be able to eat all healthy stuff. I still like wolves, and they deserve to live (to an extent)."
Management Options	***What did you like about the Minnesota plan?*** "I liked that they believed that the death of the animals is going to go way out of proportion without something that we do about it. Also they've made it so wolves have gone to endangered to threatened." ***What did you dislike about the Minnesota plan?*** "the thing i didn't like about the minnesota plan was that they haven;t ensured the saftey of the animals."

Ashley (Prompt Negotiator) continued—Project activities and strategies

Project Activities	***Strategies Used***	***Excerpts***
<u>*Identification (Low)*</u> • Wolf biology (Problem context) • Writing Notes		
<u>*Exploration (Average)*</u> • Food chain (Predators and preys) • Writing Notes	• Utilizing information embedded in WISE to revise food chain	"We're learning about wolves and doing little notes and making food chains for them. Right now I'm revising my food chain because some of my animals he really doesn't eat very often." "Well, I have a chicken as one of them, because some of them would eat chicken from the farms. But it says that most often he really eats deer, moose, hares, like rabbits and I think it was elk or something like that. So, I'm going to change chicken."
<u>*Reconstruction (Average)*</u> • Creating brochure • Wolf biology (Evidence) • Reading Notes	• Creative design • Expressing own opinions • Utilizing and revisiting Notes for brochure contents • "Knowing off the top of my head"	"My favorite was probably making the brochure [because] because I liked .. I like to do creativity type of things. And voicing your opinion and giving out facts and just making people know what's going on." "Yeah. That definitely helped because you could go back and see the type of things you might want to put in your brochure." "Well, sort of, yeah. There was a lot of things that I just remembered. But I did go back to my notes and write facts about the wolves. But most of the opinions I just knew off the top of my head."
<u>*Presentation/ Communication (Low)*</u>	• Missing a class	"Well, I didn't really get to use the chat room. I was sick that day. But the day I came in it sounded like it was helping a lot for people's opinions in their brochure and everything because they got to voice each other's opinions and use those in their brochures and see what everyone thought."
<u>*Reflection/ Negotiation (Average)*</u> • Change in the plan	• Correcting wrong information to make brochure more persuasive	"Well, some of the .. my thoughts about the wolves were not correct and that was kind of an issue, because if I had put that in my brochure, then everything would have been wrong and people could have not agreed with me because maybe they thought I wasn't very educated. So, that was something that I could resolve by using the website."

Ashley (Prompt Negotiator) continued—Artifact construction (online brochure)

Task Not Completed

Prompt Negotiator—Anthony

Concept on research, problem-solving, science and subject matter

Concept	***Definition***	***Characteristics***	***Excerpts***
Research	Finding out something you don't know	• Searching process • Utilizing websites • Documenting resutls	To find out something you don't know about something; To write a biography "I think research is … like some of it says in the word, it says, "search" so you can go online or whatever and search for what you need. Then you can document it somewhere, whatever. It also kind of means to find or search or .. it's like if you're doing a biography and you don't know anything about the person, you go to the library and find a book about the person and research their date of birth and birthday and stuff like that."
Problem-solving	Solving difficult problems	• Doing in every day life	Solving difficult problem; some problem on math homework "I like problem solving a lot. I have to do it at home because my little brother's a pest, so he'll be sitting there crying and like, I don't want to go or I don't want to be something or ..so, there's a problem ahead, how am I going to solve this? So, usually I calm him down or play with him or something like that. Or like more in math, I get a piece of paper out for every question and I use up the whole paper writing down notes that'll be helpful to me in answering the question. So, like, Jill needs to get to wherever and she only has 15 minutes to get there, what would be the shortest route? So, I'm like she just goes right on .. left on Gin Street, right on Carl Street and she'll get there in so many minutes."
Scientific investigation	Learning more about science	• Learning process • Research	To learn more about science; to research science

Concept	***Position (Not Changed)***	***Excerpts***
Populations of wolves	<u>*Pre-test*</u> • Develop a plan to manage the population	"I don't really like wolves, they scare the … out of me."
	<u>*Post-test*</u> • Develop a plan to manage the population	"Wolves aren't all that bad, but … didn't have so many that everywhere you look you see a wolf. We should manage the population."

Anthony (Prompt Negotiator) continued—Selected Notes

Topics	***Excerpts***
Wolf Biology	***What do you already know about wolves?*** "not much i know they are in the dog family and that they are endangered. i would like to know where they come from and what they usually eat." ***Some things that surprised us were:*** "There has never been an attack on humans in the US. They can run up to 40 mph's. It can eat up to 20% of their body weight."
Wolf Controversies	***Do you think wolves should be allowed to live undisturbed in the wilderness near you? Why or why not?*** "I think wolves in our area should be protected because if they weren't protected then they would be wild and they might attack defenseless sheep or other animals" ***Do you think either side is right - the farmers or the environmentalists? Why?*** "I think they both are right because i believe that the wolves can sometimes can be harmful but they can be helpful."
Management Options	***What did you like about the Minnesota plan?*** "i liked how the state of minnesota doesn't allow poeple to hunt them." ***What did you dislike about the Minnesota plan?*** "they tried to increase the amount of wolves, they already are populated enough."

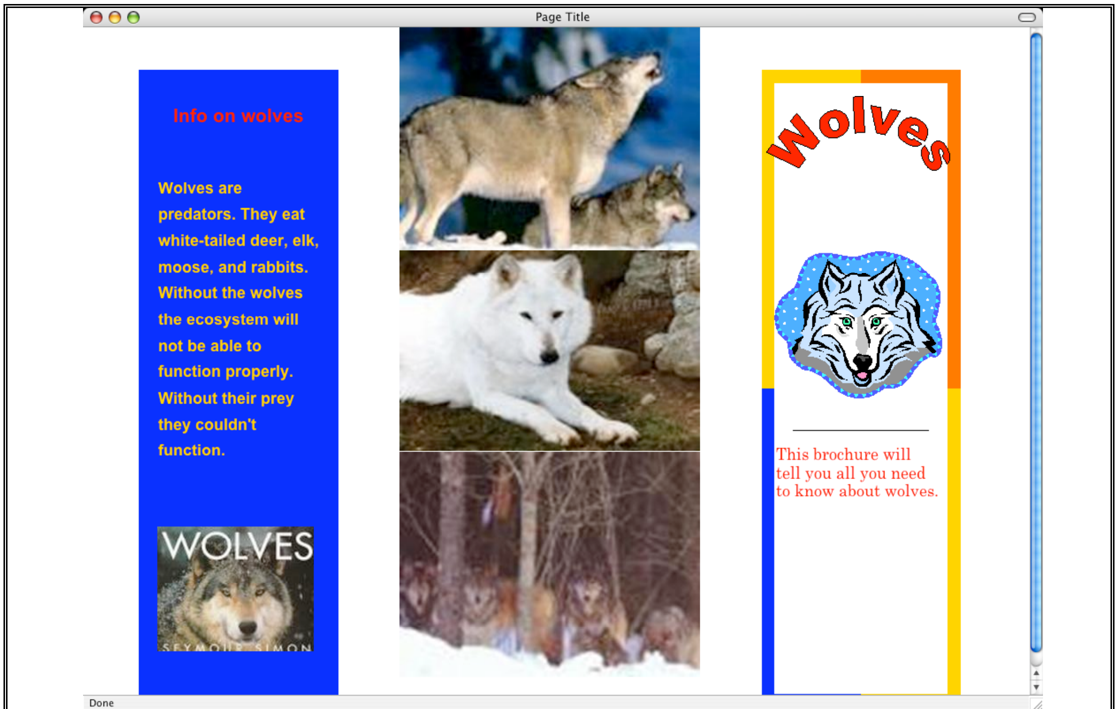
Anthony (Prompt Negotiator) continued—Project activities and strategies

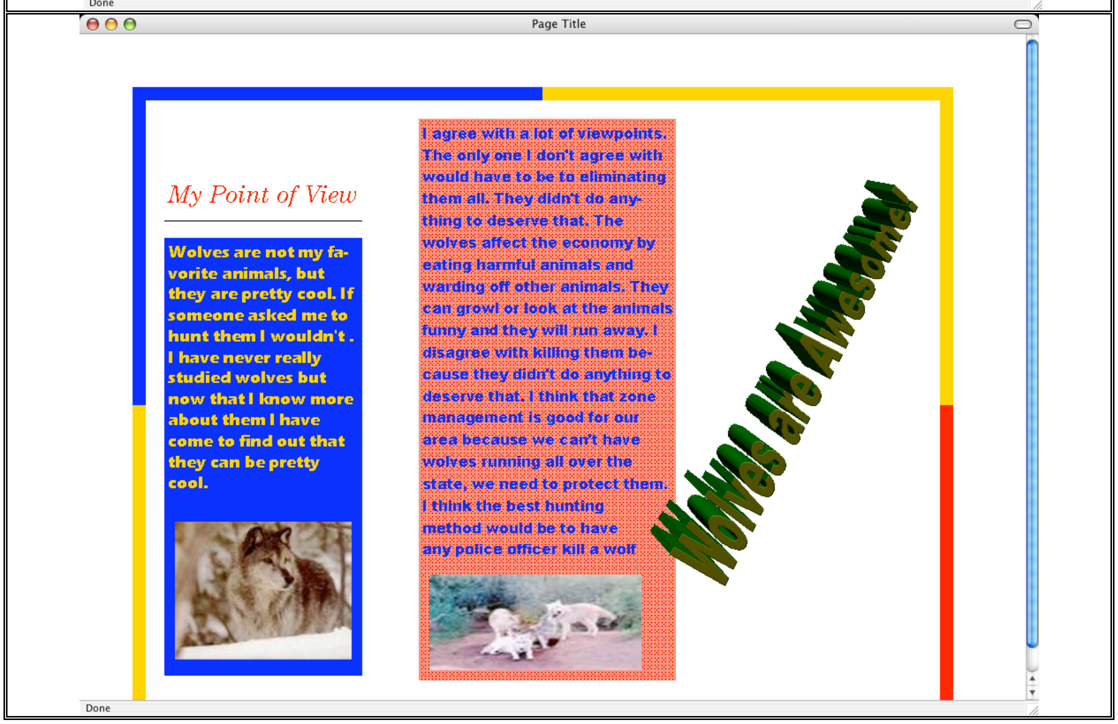
Project Activities	***Strategies Used***	***Excerpts***
Identification (Average) • Wolf biology (Problem context) • Writing Notes	• Feeling to learn more	"I like to learn more about the wolves because I'm not really the expert of wolves. So, this is pretty interesting learning more of what they eat and how they react in some places and stuff."
Exploration (Average) • Food chain (Predators and preys) • Writing Notes • No revision on the food chain	• Recognizing the lack of expertise • Enjoying typing in answers in electronic Notes • Improving typing skills • Utilizing WISE as processing tool and information source	"I especially liked how in WISE instead of having to write it all down, you could type it in there so you could look at it as some more reference to see what you put and stuff like that." "I think the most … the thing I learned is that I improved my typing skills because I used to be like a chicken pecker with these two fingers. But now, since I got to type instead of writing it down in our binder, I got to type it in the Internet. So that was really cool and I pretty much improved my typing skills a lot. And I also learned the WISE works. Because I had never heard of WISE before now and .. like, I learned wolves habitat, wolves (interruption) how wolves, what their habitat is. I learned what they eat and then what their prey eats. And so I learned kind of what their food chain is and if it decreases a little or decreases a lot or increases or whatever. The thing I will probably have to say was the best thing to learn was probably getting to go on WISE. The whole process of doing that was really cool. So, I think that was really cool."
	• Utilizing structured activities in WISE as metacognitive scaffolds	"We got to read about it and then you get to take notes on it so that … they kind of refreshed your memory. Like, if you read it then you don't say, oh, I know that now and they ask you a question and you say, oh, okay, I remember from what I just read and then you type it in and the answer. I liked that because instead of read, read, read, read, for like 8 pages of stuff and then you take the notes on it. That kind of doesn't refresh you as well. But if you read the first paragraph and then do notes and then read another paragraph and then do notes. It keeps you knowing what you just read."
	• Linking food chain design to evidence	"Sometimes I couldn't find the information from the food chain we had to do. I couldn't … it took me a while to find what their prey ate. Like the wolves, they eat moose, but I didn't know what the moose eat. So, I had to go look back and see what moose eat. And come to find out they eat pretty much the same thing that deer and rabbit eat. So, that was pretty helpful because I know what rabbits and deer eat. So, when I got to the moose, I figured out, after a while I figured out that they eat the same thing so I could just connect the moose to what they had so that was really easy."
Reconstruction (Average) • Creating brochure • Wolf biology (Evidence)	• Referring to the project guidelines • Primarily based on opinion	"Well, I've started to work on my brochure. I got all the information from WISE and the wolves and stuff. So, now I'm just following this sheet that we have to do for our brochure. So, I'm putting on all the information that

• Reading Notes		needs to be on there in the brochure." "I … for this one, it's just my point of view on wolves. So I didn't have to go to WISE and search for it because it's just my opinion."
	• Creative design	"I liked the … how you can make your own little brochure. Like make it any color you want or any style and put all the pictures that you want to. So, I think that's pretty cool."
	• Selecting & putting essential information	"All the problems I had with the first page is that I had some trouble fitting this in. so, I had to go back and find what parts that I didn't really need and delete those and then change the font with it. And so, right here I had a problem with making that funny. And so, I went to the clipart stuff, right here. That. And ______ art stuff. And I went there and that's how I got it. So, it was pretty easy."
	• Revisiting WISE info for brochure contents	"Probably the reading because I don't like to read that much. I mean, I can read well, but I just don't like to read. I just wait until the movie comes out and I'll know. But I think that wasn't the biggest one. I think that the biggest one might have been probably doing the.. well, the brochure was fun but if I didn't have all the information for it, that wasn't cool. I had to go back to WISE and then go back to the brochure. And then go back to WISE and then kept going back and forth and it took a long time."
	• Finishing up the task quickly and using free time to revisit it	"I think I do because I can go back and look at it. Say I finish it early and then she's talking about the project, I can say, oh, I remember what I had to do now and I can go back and change it and still have three days left until it's due. So, I feel comfortable with that. Another thing is I can go to other websites and if I don't find anything in them and I'm not sure about, I can go there and look at it and say, oh, yeah, I remember that and type it back in and still have a while till it's due."
	• Enjoying working on personally meaningful project	"I liked that a lot. I liked going in on the Internet and working. It's like your own personal thing. It's … you can look at someone's brochure and tell what their favorite colors are, how much they like to write, if they are interested in wolves. If they're not interested in wolves, they'll just put any old thing down and just say, I'm done and get the grade. I liked it. I think it was very organized. I think it was appropriate. I really liked it all."
Presentation/ Communication (Average) • Chat room	• Focusing on topic, important issues • Recognizing (didn't enjoy) off-topic discussion • Having more opportunities to speak without delay • Being familiar with	"Some of the times it was interesting, but some of the people kind of slacked off and they were talking about what they were going to do tonight like go see a movie. But, yeah, some people were really buckling down and talking about wolves. And the main question was what the population .. what we should do to control our population. And I said that we should have a little preserve in some national park in Georgia. And we should keep them there like stray wolves. We should bring them to there and save them so they don't die from

	chat room settings	hunger and thirst. And they could take care of them and if the wolves population get way too much, they can have that area to take them in and feed them and stuff like that." "I think you could say a lot more on the online discussion because you don't have to raise your hand and wait. You can just type it in and it's in there. But, because … you have a lot more people can answer it too because they don't have to raise their hand and they can't change subjects. They can be responding to one thing and then responding to another thing at the same time without having to wait for the teacher to call on me." "I felt more comfortable with the online chat room because I do it at home all the time. I IM and stuff like that because that's really, really popular. And I think because I do that a lot I'm used to it and so, pretty much, yeah."
Reflection/ Negotiation (Low)		
	• Increased knowledge and interest in the subject	"About the wolves? [uh huh] I think because I had no clue what the wolves ate and if they hunt in packs or anything. So, I learned where they lived and I learned that they lived a lot in Alaska. Which I had no clue. I thought Alaska was just dead. But now, I learned that wolves are .. live there and that they don't attack people. I've grown to have more interest in them and then just say, oh, wolves, just leave them alone."

Anthony (Prompt Negotiator) continued—Artifact construction (online brochure)





Steady Negotiator—Timothy

Concept on research, problem-solving, science and subject matter

Concept	***Definition***	***Characteristics***	***Excerpts***
Research	Coming up with an answer	• Utilizing tools and resources • Reading a book	Using tools that work fast to help you come up with an answer: using books at a library to find an important date or moment "It's like reading a book, but it's just on the computer and you don't have to turn the page. You just have to click with the click of a button and you can just read it. And print it out and keep it for yourself if you need it. So, having to check out a book … so, it's much easier. That's what I think research is. Just …"
Problem-solving	Solving problems through thinking and writing	• Requiring own thinking and writing process • "Thinking through" and listening	Thinking with your brain or writing out your problems to solve them: whether to pull the plug or not "Problem solving … [getting tougher] problem solving, I guess it's you solve your problems using whatever tools you can. And thinking through them and listening and stuff like that. "
Scientific investigation	Investigating an experiment	• Experiment-oriented	Investigating an experiment by doing it: to see if a contraption works, you try it

Concept	***Position (Not Changed)***	***Excerpts***
Populations of wolves	_Pre-test_ • Develop a plan to manage the population	"If we get too many they could attack in giant packs and there wouldn't be a way to step them without casualties."
	Post-test • Develop a plan to manage the population	"We don't need to kill them all therefore causing extinction. We shouldn't protect certain ones, we also shouldn't protect all of them or kill others near people. We should just make sure they don't get overpopulated. "

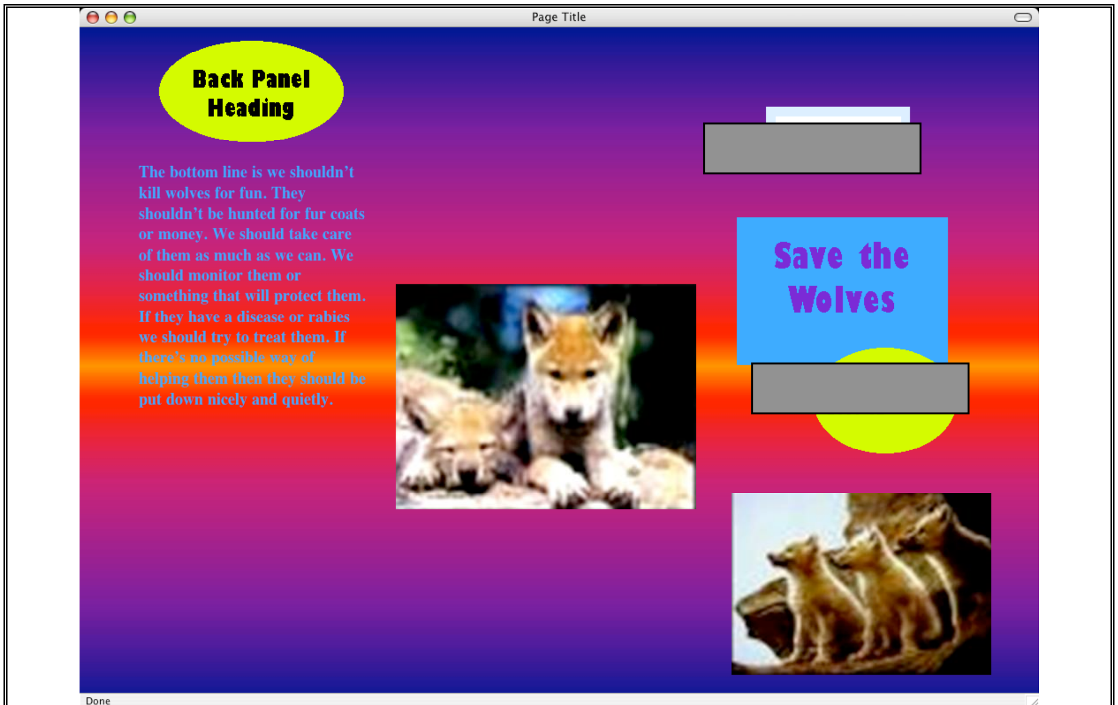
Timothy (Steady Negotiator) continued—Selected Notes

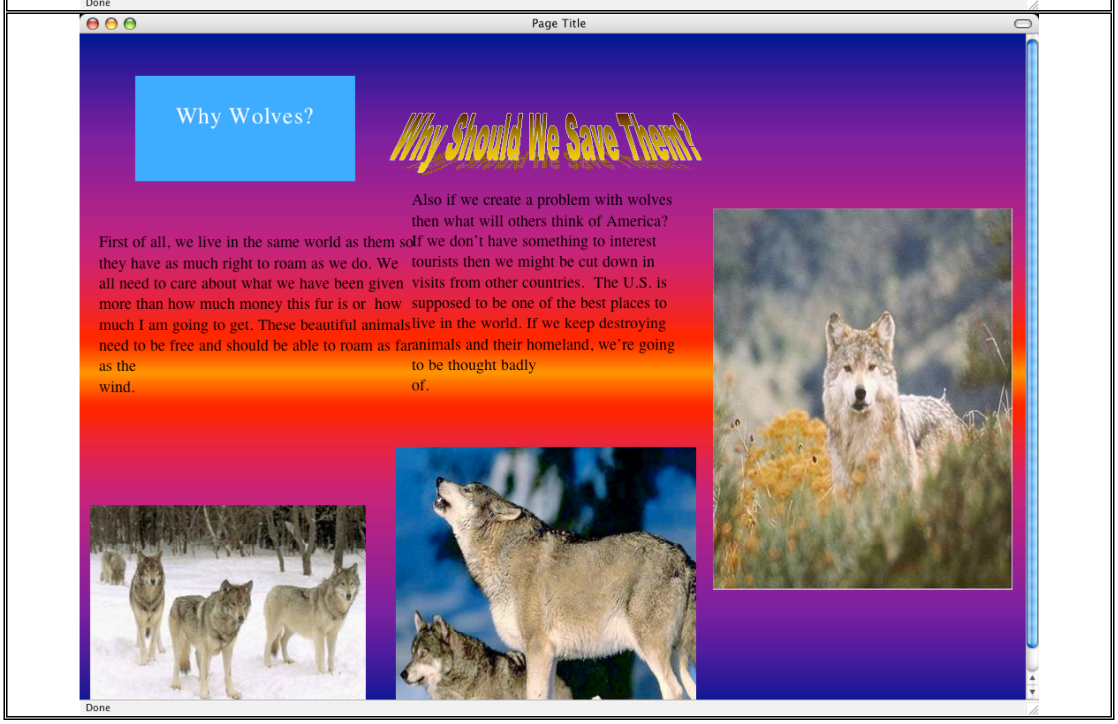
Topics	***Excerpts***
Wolf Biology	***What do you already know about wolves?*** "What they eat, why they attack humans, and how they hunt." ***Some things that surprised us were:*** "They bite with 1500 pounds of pressure per square inch; 5 times the strength of a human's bite."
Wolf Controversies	***Do you think wolves should be allowed to live undisturbed in the wilderness near you? Why or why not?*** "both because...they attack and interact." ***Do you think either side is right - the farmers or the environmentalists? Why?*** **"**both are right because...wolves do attack, but for good reason."
Management Options	***What did you like about the Minnesota plan?*** "they only kill the amount they need to therefore keeping the population of wolves high, just not to high." ***What did you dislike about the Minnesota plan?*** "they have to kill the wolves."

Timothy (Steady Negotiator) continued—Project activities and strategies

Project Activities	***Strategies Used***	***Excerpts***
Identification (Average) • Wolf biology (Problem context) • Writing Notes	• Using prior interest and experience in subject matter	"Well, last year in fifth grade we were talking about wolves. We were reading stories, so we decided to do … why not adopt one? And my teacher went online and found out that you can adopt one in Yellowstone Park. [which park] Yellowstone Park. [Is in this area around here] no, it's over in the Rocky Mountains, Yellowstone National Park. So, we adopted one. [class] yeah, our class did. We didn't have to pay any money, we just looked after it and once someone adopts it, it's protected and it can't be hunted. It gets a collar around it which they can track it with. And they give you an update every week and say how he's doing .. if he's eaten well and if he's doing okay and all. So, they keep an eye on him and it's very cool. They sent us a picture every week with the letter. But sometimes they would send us more than one, two or three. And sometimes they .. once they gave us a picture of the whole pack. And the alpha male and the alpha female would be in the pack and were real cool. On the snow and in a blizzard. And it was real cool."
Exploration (Average) • Food chain (Predators and preys) • Writing Notes	• "Getting to be creative" for designing food chain • Remembering and memorizing facts • Revising Notes after reading facts	"I would have to say the making the food chain, that was fun. It was an activity. So, [because] I don't know. I guess you get to be creative. You can use whatever animals you want and different colors and stuff like that, so." "I remembered from the facts I read in here." "Well, this website where we read all these cool facts about wolves and after each section we wrote notes. They asked us a question and we answered … and they called it notes. And then we did another activity where we got to make the food chain. And then we revised it later after we learned what they ate and all. And so, that's pretty much it."
Reconstruction (Average) • Creating brochure • Wolf biology (Evidence) • Reading Notes	• Being creative and learn at the same time	"I'd have to say doing the brochure because you got to be creative and learn at the same time."
Presentation/ Communication (Average) • Chat room	• Having confidence in expressing ideas	"Face to face, it's kind of hard because you can get nervous because you're right there with them. But in the chat room, sometimes you can have nicknames, so they won't know who you are. Which we didn't for this chat room. So, you don't have to be nervous. You can just type what you want and they can read it and respond back and you don't have to be scared or nervous of things."
Reflection/ Negotiation (Low)		

Timothy (Steady Negotiator) continued—Artifact construction (online brochure)





Steady Negotiator—Zachary

Concept on research, problem-solving, science and subject matter

Concept	*Definition*	*Characteristics*	*Excerpts*
Research	Finding events that you never knew	• Information finding (events) • Learning process	Finding things that you would have never known; I learned about burritos “Social Studies, basically. Because Social studies, it’s a bunch of events. [what] a bunch of events that have happened. And it’s pretty hard to learn them in the textbook. So, that’s why the web is good for Social Studies”
Problem-solving	N/A	• Math related	lame!!; math class “Like just basically solving problems. And that’s it. [an example … a math problem?] like, I had three oranges and I ate one and I only had two.”
Scientific investigation	N/A	• Cool	Cool (murder mysteries); forensics

Concept	*Position (Not Changed)*	*Excerpts*
Populations of wolves	<u>*Pre-test*</u> • Develop a plan to manage the population	“They are cool and why destroy them all.”
	<u>*Post-test*</u> • Develop a plan to manage the population	“Wolves are so cool, but they might kill farm animals.”

Zachary (Steady Negotiator) continued—Selected Notes

Topics	*Excerpts*
Wolf Biology	<u>***What do you already know about wolves?***</u> [He did not answer in his own words. He copied and pasted from the WISE website] <u>***Some things that surprised us were:***</u> [He did not answer in his own words. He copied and pasted from the WISE website]
Wolf Controversies	<u>***Do you think wolves should be allowed to live undisturbed in the wilderness near you? Why or why not?***</u> “protected because... there are so little left.” <u>***Do you think either side is right - the farmers or the environmentalists? Why?***</u> **“**Both are right because the number of wolves that can live in a particular habitat is defined as the Physical Carrying Capacity.”
Management Options	<u>***What did you like about the Minnesota plan?***</u> “It was helpful.” <u>***What did you dislike about the Minnesota plan?***</u> “nothing”

Zachary (Steady Negotiator) continued—Project activities and strategies

Project Activities	***Strategies Used***	***Excerpts***
<u>Identification (Average)</u> • Wolf biology (Problem context) • Writing Notes	• Utilizing prior interest influenced by previous reading about subject matter • Linking prior experience and project topic	"I read that in some small town in Wisconsin, this kid he was jogging and he wasn't found until several days later and they found him all gory … gored up, bloody. And then, the mountain .. then the people the searching for him were then attacked by a mountain lion. And they got out away and so, now all the mountain lions there were sent to some park and that's basically it."
<u>Exploration (Average)</u> • Food chain (Predators and preys) • Writing Notes • No revision on the food chain	• Facing difficulties finding out relevant information • Feeling there are too many words in WISE	"I'm working on this … the wolf project and I'm doing my notes. And this is pretty tough to find out what to write. And I like … it gives you a lot of information, though. And I can't wait until I get to go in the chat room because that would be cool." "I'm trying a .. I'm trying to make it sound .. I'm trying to do ..say what the article is saying but in my own words sort of. But it's pretty hard to search for what you're looking for." "I didn't like that because it was … it had too much … too many words in it. Like, it could have just summed it up a little more."
<u>Reconstruction (Average)</u> • Creating brochure • Wolf biology (Evidence) • Reading Notes	• Summing up facts • Not being able to strategically connect evidence to argument ("just thinking about it" • Recognizing difference between prior and current project • Expanding and developing more ideas	"I guess just summing it all up except, it would … but I'm still going to write it but basically what the whole thing is going to be all about in a couple of sentences." "I just thought about it. Because I know they shouldn't be hunted but they shouldn't be able to live freely amongst everybody." "I liked … most confident? Maybe it was because, like, I already did a project on it. [like since third grade?] yes .. no fourth. [_____ about wolves] in science [a little about wolves and this project] but I didn't talk about the same things. In this project I talked more about their features like their coat and how their hearing was and how their eyes were. But, in this project, I'm talking about how to save them."
<u>Presentation/ Communication (High)</u> • Chat room	• Enjoying talking to many classmates at one virtual place • Overseeing different views • Evaluating others' work	"The chat room, definitely. [okay, why] because, you could express views and it's not like people are really going to talk about wolves without a computer because that would be pretty hard having everybody talk at once. But, I think. I think that it was really cool getting to talk with your classmates because everybody has different views. Most of the kids liked wolves though. A couple of kids didn't like it. But there was this one anonymous guy. I didn't like him. I even put up a comment, "this anonymous guy sure seems to be a jerk." And Miss Adams said she knew how to enter anonymously and so I asked miss Adams if that was her and she said, no. And, but a lot of kids were acting silly, like putting all these question marks and all these misspellings and …

	cause a couple of them were so hard to understand. Yeah." "Well, I … when the kids are acting silly, I responded and I said, shouldn't we be talking about wolves? I also put .. I also agreed with a lot of people. And I didn't have very long ones like some kids did but I think they were pretty good."
Reflection/ Negotiation (Low)	

Zachary (Steady Negotiator) continued—Artifact construction (online brochure)

Task Not Completed

Steady Negotiator—Hailey

Concept on research, problem-solving, science and subject matter

Concept	***Definition***	***Characteristics***	***Excerpts***
Research	Looking for info on the Internet or in books	• Information-finding • Fun	Looking for info on the Internet or in books; rain forest animals in… "I think that research is just looking for information and just having fun while you're doing it." "[for example] Well, we just … well, we did a short thing, one time where we had to go to all these websites and find out all this information about different things. And we had to do a worksheet but it was on the computer. And we had to write them in and it was just fun because we learned more about Tsunamis … so."
Problem-solving	N/A	• Finding solution	Mysteries and math; Nancy drew books, 7*5/4+1*0
Scientific investigation	N/A	• N/A	

Concept	***Position (Not Changed)***	***Excerpts***
Populations of wolves	<u>*Pre-test*</u> • Provide complete protection for wolves	"I don't want them to get hunted"
	<u>*Post-test*</u> • Provide complete protection for wolves	"I think we should protect wolves. They never did anything to us."

Selected Notes

Topics	***Excerpts***
Wolf Biology	<u>***What do you already know about wolves?***</u> "How they are part of the dog? What they eat. What eats them." <u>***Some things that surprised us were:***</u> "They sometimes don't live until their 1st birthday! Gray wolves can be gray, black, brown, white or tan!"
Wolf Controversies	<u>***Do you think wolves should be allowed to live undisturbed in the wilderness near you? Why or why not?***</u> "Because...they're more scared of you than you are of them. And they don't attack people very often." <u>***Do you think either side is right - the farmers or the environmentalists? Why?***</u> **"**both are right because...both have their opinions and i can't decide.."
Management Options	<u>***What did you like about the Minnesota plan?***</u> [Did not answer this question] <u>***What did you dislike about the Minnesota plan?***</u> [Did not answer this question]

Hailey (Steady Negotiator) continued—Project activities and strategies

Project Activities	***Strategies Used***	***Excerpts***
Identification (Low) • Wolf biology (Problem context) • Writing Notes		
Exploration (Average) • Food chain (Predators and preys) • Writing Notes • No revision on the food chain	• Using drawing features (fun) • Finding and utilizing information to answer questions • Utilizing notes to save answers	"The food chain is fun because you just get to change the colors and make lines do weird things" "I'm trying to figure out this. But I have no clue what the answer is. So, I'm just going to read this and go back to that." "It's [notes] easier to do it, because you don't lose it on the computer. And it's easier." "I learned a lot about the wolves and what they do and how they do stuff and what kind there are and what they eat. And I learned by answering the questions on the WISE and it was easy to do because it was online. You don't lose things. So, that was a lot of fun."
Reconstruction (Low) • Creating brochure • Wolf biology (Evidence) • Reading Notes	• Not finishing the brochure design due to missing classes	"I didn't get to finish that either. Not yet."
Presentation/ Communication (Low) • Chat room	• Not using the chat room due to missing classes	"I was sick so I didn't get to do the chat room and stuff."
Reflection/ Negotiation (Low) • No Change in the plan	• N/A	

Hailey (Steady Negotiator) continued—Artifact construction (online brochure)

Task Not Completed

Steady Negotiator—Kimberly

Concept on research, problem-solving, science and subject matter

Concept	***Definition***	***Characteristics***	***Excerpts***
Research	Finding information about a topic	• Information-finding	"Well, I think that you would … like you have a topic and you find out information about it."
Problem-solving	Solving a problem	• Using prior knowledge • Math-related	"Problem solving, like you have a problem and you try to solve it. You say, like your head and mathematical and stuff."
Scientific investigation	N/A	• N/A	

Concept	***Position (Not Changed)***	***Excerpts***
Populations of wolves	<u>*Pre-test*</u> • Develop a plan to manage the population	"I don't want wolves running around all the time. They can also carry a sickness (rabies). If they bite you, then we can get sick. I don't mind a few wolves, but too many can cause problems."
	<u>*Post-test*</u> • Develop a plan to manage the population	"I think we should eliminate some wolves and protect some wolves."

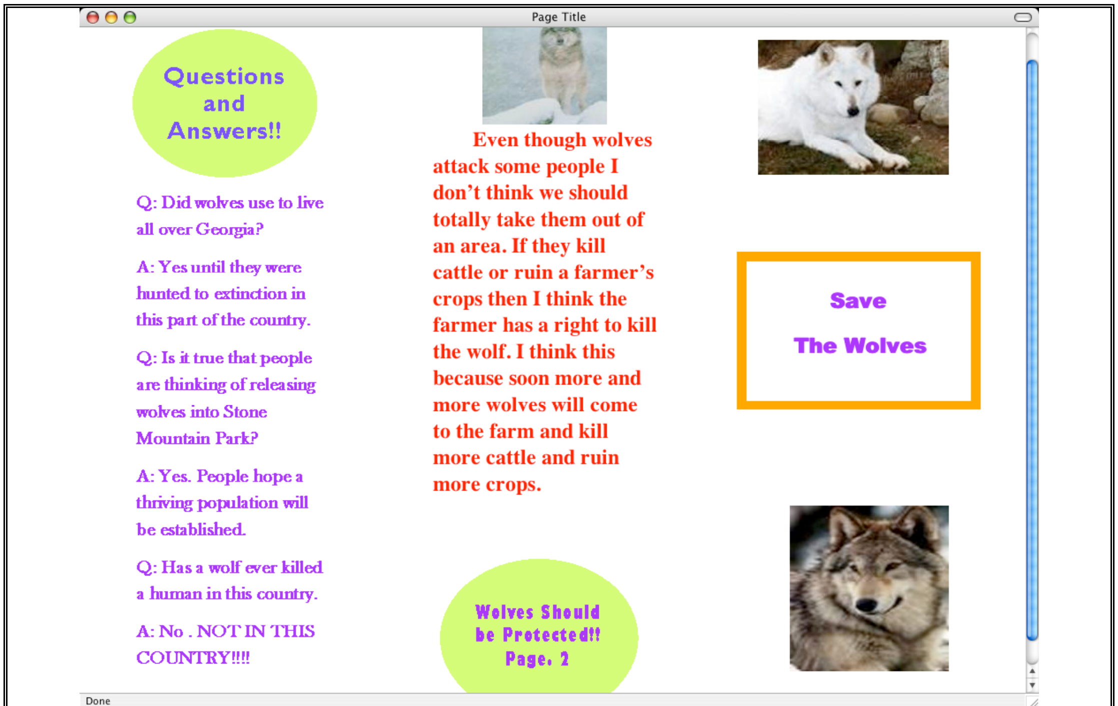
Kimberly (Steady Negotiator) continued—Selected Notes

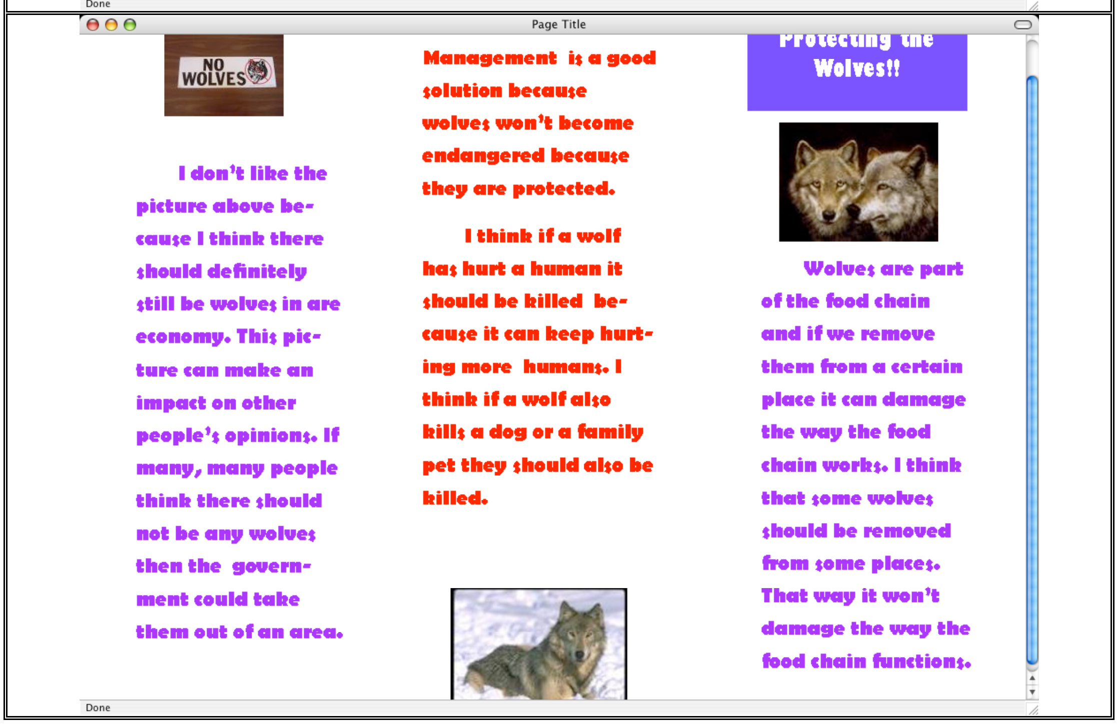
Topics	***Excerpts***
Wolf Biology	<u>***What do you already know about wolves?***</u> "1. How many wolves are killed each year? 2.What percent of wolves carry sicknesses? 3. What is the most killed animals by wolves?" <u>***Some things that surprised us were:***</u> "1.Most wolves die before their first birthday. 2.About 2,500 wolves live in Minnesota. 3.A wolf's jaw is 5 times that of a human."
Wolf Controversies	<u>***Do you think wolves should be allowed to live undisturbed in the wilderness near you? Why or why not?***</u> "protected. Because... wolves are part of the food chain and if we eliminate them we could mess up the food chain between the animals." <u>***Do you think either side is right - the farmers or the environmentalists? Why?***</u> **"**both are right because... wolves do hurt farmers crops sometimes, but we also need the wolves to live in it's natural state."
Management Options	<u>***What did you like about the Minnesota plan?***</u> "1.They are trying to ensure long-term survival of wolves. 2. Killing of wolves in the defense of a human life will continue to be allowed." <u>***What did you dislike about the Minnesota plan?***</u> "I like everything about the Minnesota plan."

Kimberly (Steady Negotiator) continued—Project activities and strategies

Project Activities	***Strategies Used***	***Excerpts***
<u>*Identification (Average)*</u> • Wolf biology (Problem context) • Writing Notes		
<u>*Exploration (Average)*</u> • Food chain (Predators and preys) • Writing Notes	• Making a decision regarding wolf population • Taking Notes for for formative self-assessment • Having difficulties reading long text • Using Notes as self-assessment • Having difficulties connecting different animals • Having preference for clear, definite knowledge representation	"I liked it a lot. It made me think about what I'd really want to do if I have to make a decision on what to do with the wolves and I've .. I think it was really cool." "Yes, because then it was really like testing my brain to see if I really comprehended all of it. And that way, I could actually type in and put it into words." "Well, sometimes when they would give you links to other pages, the pages would be so long and you wouldn't have time to read all that and so, then you'd have to get off the other page and keep going so you wouldn't get to read all the information that was there. I just think it was really long." "I did because that way when you would take the notes on them or answer the questions you would just make sure that you comprehended everything really good." "Well, I didn't like that one thing where we had put what the wolves ate. Like we had to connect al the different things with what they ate and what those animals that they ate and all that. It was just confusing [the food chain] yes. Well, I could figure it out but then when you would put the arrows to the different things, it got confusing because they would overlap and it would get confusing."
<u>*Reconstruction (Average)*</u> • Creating brochure • Wolf biology (Evidence) • Reading Notes	• Getting help from instructor for different ideas • Not enjoying repetition of putting the same info	"Well, she would help me by giving me different ideas and saying, oh, you can put this into your brochure or maybe try to include this. Giving me different ideas to help me." "No, because I think, it was fun but then we had to put all that information back into a brochure when we already answered all the questions and then it was just sort of took a long time too for me because I was out and I had to make it up."
<u>*Presentation/ Communication (Average)*</u> • Chat room	• Comparing ideas	"I used it a good bit and I like asked questions about the wolves on there and I got people's opinions compared to mine."
<u>*Reflection/ Negotiation (Low)*</u>		

Kimberly (Steady Negotiator) continued—Artifact construction (online brochure)





Unfocused Trial & Error Student—Steven

Concept on research, problem-solving, science, and subject matter

Concept	***Definition***	***Characteristics***	***Excerpts***
Research	Looking up information	• Information finding	finding info; NHD research "I believe research is going into a book and internet, anything that can give you information on something you're studying to like get more info on it."
Problem-solving	Getting info to solve a question	• Information-gathering • External-driven (question given)	solving questions asked; math practice book "I would say, getting … well, to tell you the truth. I would think it's just solving a problem but that would be too simple. So, I'd have to say, it's getting info to solve a question given to you."
Scientific investigation	N/A	• N/A	Average

Concept	***Position (Not Changed)***	***Excerpts***
Populations of wolves	*Pre-test* • Develop a plan to manage *Post-test* • Develop a plan to manage	 "I don't really want wolves to die out because they have feelings too" "They are sometimes dangerous."

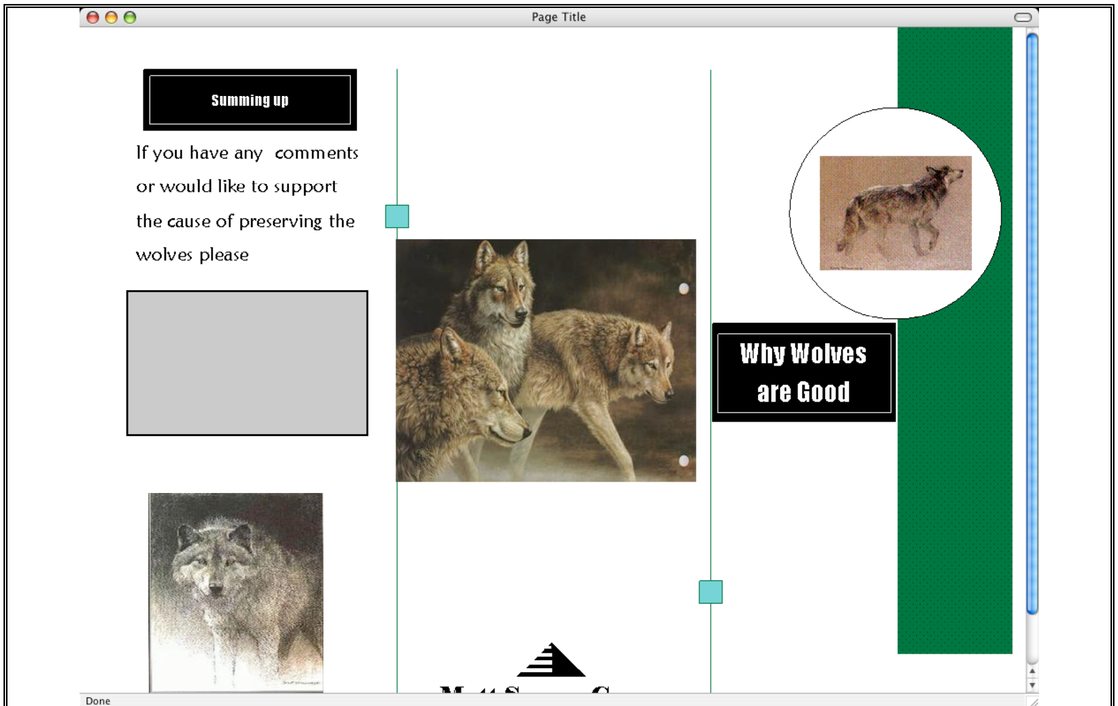
Steven (Unfocused Trial & Error Student)—Selected Notes

Topics	***Excerpts***
Wolf Biology	***What do you already know about wolves?*** "They can be dangerous. They are losing their habitat.We are killing them." ***Some things that surprised us were:*** "Most of them die before their first birthday. Wolves bite 5 times stronger than humans."
Wolf Controversies	***Do you think wolves should be allowed to live undisturbed in the wilderness near you? Why or why not?*** "protected Because...they haven't hurt us intentionally so why hurt them" ***Do you think either side is right - the farmers or the environmentalists? Why?*** **"**both are right because...they should be able to do what ever they need to do to make themselves happy"
Management Options	***What did you like about the Minnesota plan?*** "everything" ***What did you dislike about the Minnesota plan?*** "not anything"

Steven (Unfocused Trial & Error Student)—Project activities and strategies

Project Activities	***Strategies Used***	***Excerpts***
Identification (Low) • Wolf biology (Problem context) • Writing Notes	• Enjoying freedom and flexibility of playing games during project • Lack of interest in topic • Lack of interest in doing what I have to do (required tasks) • Lack of focus	"Just the atmosphere of my friends and playing games when I'm done. [here] yeah. I'm a big fan of games." "Because you have a lot of freedom in this class but you have something to do. Like, you have this specific idea but you have all this general stuff around it that you can work on like different pages on something or research or pictures." "Projects, projects, projects, projects, projects. Just projects. I'm not a really big fan of projects but when they're fun it's okay. But, still there's a lot of stuff you have to do by a certain point." "It's just I kind of don't like having to do projects where you have to do work." "I can't focus, you know. And all that kind of stuff."
Exploration (Low) • Food chain (Predators and preys) • Writing Notes	• Reading info embedded in WISE • Disliking too much info • Finding structured activities useful • Playing games • Finding WISE "keeping myself slightly entertained"	"Yes. [you can tell me more about that, not just yes, no] well, it just sort of supplied most of the information with links to other sites and stuff. And there were those five chapters that really helped a lot." "Well, it was accurate, I would think. And it was plentiful. And they didn't stretch it. told the truth like stretch it too far. Tell too much or whatever." "I liked it because they just set it up into small parts. And that really narrowed it down for me." "Because it (game) keeps me entertained while I'm doing something really boring." "Well, not completely boring. That's why I said a little boring. And so, yeah. I just had to keep myself slightly entertained. And I would just go onto my favorite website, Dean's workshop and just check it out."
Reconstruction (Low) • Creating brochure • Wolf biology (Evidence) • Reading Notes	• Enjoying making artifacts with computer	"Putting the brochure together. [really, because] because I like to make stuff. [with computers] with computers, yes."
Presentation/ Communication (Low) • Chat room	• Recognizing limitations of interface	"Honestly. I didn't like the chat room at all. It was too hard to get something out and you just wanted to say something so you had to scroll to the very top, click on insert new note and type a lot and finally enter it. And by the time you replied to what you're trying to reply to, there's like ten other replies or whatever."
Reflection/ Negotiation (Low)	• Change in perceptions about wolves • Change in attitude toward wolves	"Well, I learned a lot about wolves and how they don't really attack humans. I thought they did and well, I just learned about wolves." "At the very beginning, I hated wolves and now they're okay."

Steven—Artifact construction (online brochure)



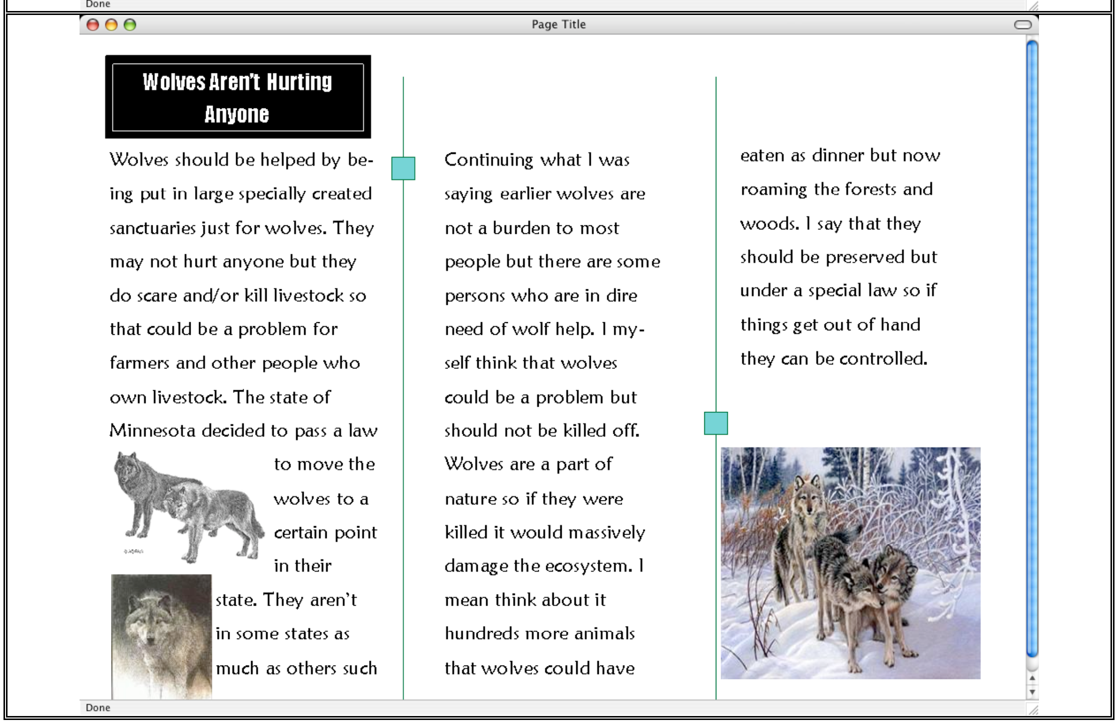
Page Title

Summing up

If you have any comments or would like to support the cause of preserving the wolves please

Why Wolves are Good

Done



Page Title

Wolves Aren't Hurting Anyone

Wolves should be helped by being put in large specially created sanctuaries just for wolves. They may not hurt anyone but they do scare and/or kill livestock so that could be a problem for farmers and other people who own livestock. The state of Minnesota decided to pass a law to move the wolves to a certain point in their state. They aren't in some states as much as others such

Continuing what I was saying earlier wolves are not a burden to most people but there are some persons who are in dire need of wolf help. I myself think that wolves could be a problem but should not be killed off. Wolves are a part of nature so if they were killed it would massively damage the ecosystem. I mean think about it hundreds more animals that wolves could have

eaten as dinner but now roaming the forests and woods. I say that they should be preserved but under a special law so if things get out of hand they can be controlled.

Done

Unfocused Trial & Error Student—Kevin

Concept on research, problem-solving, science, and subject matter

Concept	***Definition***	***Characteristics***	***Excerpts***
Research	Looking up information	• Information finding	Looking up info; NHD "To me, it's like thinking up a specific topic and doing .. getting more information on it"
Problem-solving	N/A	• Essential for solving textbook problems • Using resources • Boring	Boring; math "Using any resource available to solve a problem. Like, if you need to solve a problem, like, what you need to find out. Like, for us, instance for homework, there's homework now and homework now helps you solve your problem for what you need to do for homework." "[for example] First, homeworknow.com . and also for research like we said before, because you might not know all about it and if you don't really have very many books on it, you could use the computer."
Scientific investigation	N/A	• Fun • Discover what scientists found	Sometimes fun; invention convention
Concept	***Position (Not Changed)***		***Excerpts***
Populations of wolves	<u>*Pre-test*</u> • Develop a plan to manage <u>*Post-test*</u> • Develop a plan to manage		 "I don't really want wolves to die out because they have feelings too" "I don't think wolves should be killed because they're living creatures like us"

Kevin (Unfocused Trial & Error Student)—Selected Notes

Topics	***Excerpts***
Wolf Biology	<u>***What do you already know about wolves?***</u> "they are.... damgerous. they have sharp teeth. they are similar to doggies." <u>***Some things that surprised us were:***</u> "-they sometimes do not eat humans -they eat upm to 1500 pounds of pressure from more -they only eat humans in India"
Wolf Controversies	<u>***Do you think wolves should be allowed to live undisturbed in the wilderness near you? Why or why not?***</u> "protected because...they only attack for food and protection." <u>***Do you think either side is right - the farmers or the environmentalists? Why?***</u> **"**both are right because...the enviromentalist just want to protect the wolves"
Management Options	<u>***What did you like about the Minnesota plan?***</u> "I think tis pretty good because they still keep the wolves, but they keep it under control." <u>***What did you dislike about the Minnesota plan?***</u> [Did not answer this question]

Kevin (Unfocused Trial & Error Student)—Project activities and strategies

Project Activities	***Strategies Used***	***Excerpts***
<u>*Identification (Low)*</u> • Wolf biology (Problem context) • Writing Notes	• Lack of interest in topic • Interest in using computers and internet • Finding a challenging problem • Having preference for project-based activities • Recognizing and appreciating different pedagogies in class • Convenience use of the web/computers	"…This project, I'd say it's kind of average because I'm not much of a wolf fan but I do like using the computer and going on the internet." "Mostly from the WISE website. It taught me a lot of stuff like their diet and where they live and I never really knew it when they were endangered and all that." "In this class, we don't just learn by her saying it to us. Like, she takes us step by step and we learn that way while using the computer. While doing an activity, she'll tell us what to do and we'll do it. And in my science class that I'm taking, they'll just tell us straight out or we'll have to read from the book or do worksheets or something like that."
<u>*Exploration (Low)*</u> • Food chain (Predators and preys) • Writing Notes • No revision on the food chain	• Getting procedural assistance from peers • Revisiting Notes	"My friends helped me a lot sometimes. Like, when I was confused on where I should go, my friends would just tell me because they would already be ahead of me. Or like what I should do." "Those [WISE Notes] are cool. They were cool how they just recorded what we learned from that kind of section. Like, if we ever forget we could just go back and look at them."
<u>*Reconstruction (Low)*</u> • Creating brochure • Wolf biology (Evidence) • Reading Notes	• Lack of supporting evidence	
<u>*Presentation/ Communication (Frequent Use)*</u> • Chat room	• Personal preference • Learning style	"I liked the chat room. Yeah. [because] well, it was just really fun to just chat with people online. I think it was just really fun. [fun because] I don't know what but it was just fun. I just like to do it."
<u>*Reflection/ Negotiation (Low)*</u>	• Conceptual change in wolves	"I learned that wolves aren't mean and terrifying as a lot of people think they are. It's just that they need food and every living thing needs food. Well, at first I thought they just did it because that's just what they do. But, they really did it just for food. I thought they just did it to hunt or something like that."

Kevin—Artifact construction (online brochure)