# KNOWLEDGE INTEGRATION ENVIRONMENT *PROJECT*

Annual Report

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**Marcia C. Linn**
**Principal Investigator**
**School of Education**
**University of California, Berkeley**
**4611 Tolman Hall #1670**
**Berkeley, CA 94720-1670**

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## • INTRODUCTION

This year has seen the Knowledge Integration Environment (KIE) develop from a prototype to a testable software environment. KIE is an instructional computer environment that engages middle and high school students in scaffolded inquiry with scientific evidence from the Internet, resulting in a completed project.

The environment consists of a set of complementary software components which provide browsing, note-taking, discussion, argument-building, and guidance capabilities. This report presents progress in software development, as well as classroom research relating to the design of KIE curriculum projects.

In the summer of 1995, significant software design and implementation occurred, with trial and refinement throughout the school year. A number of KIE curriculum projects were developed in accordance with our Scaffolded Knowledge Integration (SKI) framework. These projects have been tried in many classes, providing a vehicle for continuing educational research into various aspects of SKI which are directly relevant to further developing the KIE software.

Additionally, we have sought to include members of our extended scientific and educational families in the process of reviewing the software and developing relevant Internet projects. Symbolic of this extension to the scientific community is our KIE Web site, which was launched this year in order to provide Internet access to an outline of the theoretical framework (SKI) and software (KIE), as well as several other services: links to our own related research (CLP); links to all of our existing Internet evidence (known as the "NED," for

Networked Evidence Database); and open invitations to download the software for review, and perhaps even to join us in forming a KIE Liaison relationship. Overall, this year has seen a flurry of research and development activity, which will be discussed here in separate sections addressing (a) software developments, (b) KIE projects, (c) classroom research, and (d) dissemination of KIE to educators and scientists. Finally, the members of the KIE project have been active this year in publishing and presenting various facets of the research, which is reflected in the attached list of presentations and publications.

While Marcia Linn, the principal investigator on the KIE project, has been on sabbatical this year at The Center for Advanced Studies in the Behavioral Sciences, she has maintained close contact with the team members through weekly meetings and regular telephone and electronic communications. In addition, James Slotta has worked as a postdoctoral scholar to coordinate research and administrative activities.

# • SOFTWARE DEVELOPMENT

## • *Overview*

At the outset of this funding year (June, 1995), we had just completed our first classroom testing of the prototype KIE software, which provided us with a good source of insight into its strengths and weaknesses. Building on prior research in the classroom, we have designed all aspects of the KIE software in accordance with a specific pedagogical framework, known as Scaffolded Knowledge Integration (see Linn, Songer and Eylon, in press). The general aim of the SKI framework is to help students gain a robust and predictive understanding of science by encouraging them to make connections between scientific concepts and relate these concepts to personally relevant situations and problems. Thus, all software design decisions attempt to facilitate such connections, as well as provide vital support for the learner, including guidance, feedback, and social supports.

The SKI framework has four main components: (a) identifying new goals for learning, (b) making thinking visible, (c) encouraging lifelong learning, and (d) providing social supports. The Knowledge Integration Environment supports three types of projects: *theory comparison* to help learners distinguish ideas in their repertoire; *argument exploration* to help learners expand their repertoire of ideas and to recognize partisan or invalid arguments, such as those they might encounter on the Internet; and *design* to help learners draw on scientific information to solve complex problems such as creating an energy-efficient home. To illustrate, Figure 1 shows a screen shot from a theory comparison and argument exploration activity. The software components of the KIE learning environment have been designed to support the use of Internet resources within these three types of activities, with the overarching goal of enabling the SKI framework to be applied in a wide variety of science topics. It is composed of a complementary set of both custom and commercial software, designed to augment the desired instructional approach. KIE features the following custom software components:

- *KIE Tool Palette*—the control panel for working in KIE (see Figure 1);
- *Netbook*—a Net-oriented group notebook that allows students to organize, edit, and browse their project-related documents (see Figure 1);
- *Networked Evidence Database (NED)*—collections of scientific evidence from the Net, project developers, and created by students (see Figure 2);
- *On-line Guidance ("Mildred")*—an on-line guidance system which provides supporting prompts and feedback as students work on activities (see Figure 3);
- *SenseMaker*—an argumentation tool which allows students to categorize, rate, and take notes on the set of evidence associated with a project (see Figure 4);
- *SpeakEasy*—a multimedia discussion tool which allows students to conduct structured conversations about their scientific ideas over the Net (see Figure 5).

- *The KIE Tool Palette and Netbook*

The KIE Tools palette scaffolds student activity while in KIE, and the Netbook provides organization for the students' Net-related documents (see Figure 1). We have continued to make improvements to these tools based on feedback from teachers making use of them in their classrooms as well as refinements in our approach. Students can organize their work from multiple KIE projects using the Netbook, and choose from various activities within a project. A checklist allows for self-monitoring of progress, as well as control of activity-specific guidance. The KIE Tool Palette enables students to manage screen "real-estate" by switching between five different applications: the Netscape Web Browser, ClarisWorks editing environment, the SpeakEasy conversation tool, the SenseMaker argument editor, and the Netbook. The Tool Palette also provides constant access to the KIC (Knowledge Integration Coach) and activity checklist. While this year's work in the classroom has offered us insight into improvements for the Netbook and Tool palette, Figure 1 shows its current interface.

- *The Networked Evidence Database and NED Manager*

We have continued to expand our collection of Internet-based scientific evidence which is instructionally scaffolded. We have also made it easier for others to contribute new pieces of evidence to the database. The Networked Evidence Database (NED; see Figure 2) presently consists of Internet evidence about science concepts primarily in topics of thermodynamics and light, as this has been the focus of our own research and development. However, the NED is currently expanding into other conceptual domains, including biology and earth science. Evidence in the NED can be drawn from existing Internet material (e.g., by adding relevant Web sites to the NED), or can be created specifically in a KIE project. The NED is currently composed of approximately half of each type of evidence. All NED items consist of the actual Web-based “evidence” as well as a “NED” Web page, which contains guidance and preface information for the student, as well as some keywords, topic area, and other information that is useful for database purposes (e.g., so that the evidence can be used appropriately in developing future KIE projects). The student does not necessarily see this latter sort of information when surveying the evidence as part of a KIE project. Whenever a piece of NED evidence is surveyed from a KIE project, the NED page is displayed first. Student get some guidance and context information before viewing Web evidence. This “advanced organizer” helps students interpret complicated and confusing Web evidence.

Evidence in the NED can come from KIE project developers who wish to make specific evidence available, from existing resources on the Net, or from the students themselves as a product of their classroom inquiry. Students collaboratively create evidence to be published in the NED in KIE projects. For example, a student team may author a piece of evidence summarizing a lab they performed in class or they may make a digital movie of a particular phenomena relating to a science concept in class. Alternatively, evidence may come from newsgroup discussions taking place on the Net or from other information resources on the Web.

The NED manager software makes adding new evidence to the Web easy, allowing users to access and modify the NED over the Web. The NED Manager is an integrated collection of programs that allows teachers, researchers, and other contributors to perform database management functions through a common Web interface. Like any other database, the NED Manager provides users with the functionality to create, modify, copy, or delete any evidence contained in a central repository (NED). By using the NED Manager, project developers can inspect any evidence created by the community at large and reuse pieces of evidence already in the database. Additionally, the software lets users search the catalog of evidence and verify the consistency of the links in the evidence pages. By providing a convenient interface to the evidence database, the NED Manager facilitates the creation of projects.

- *On-line Guidance*

KIE on-line guidance (known to the students as "Mildred, the Cow Guide"; see Figure 3) provides guidance to students as they complete all aspects of a KIE project. Mildred provides guidance at three levels. *Project-specific scaffolding* guides students to think about what the main idea is that they should keep in mind as they work on the various activities and look at the evidence for a particular project. *Activity-specific hints* help students as they work on a particular aspect of the project. For example, the student might be reminded of the goal of writing a critique of a piece of evidence, and what is appropriate to include in such a critique. *Evidence-specific hints* guide the student to critically evaluate evidence in the NED. All of these levels of scaffolding model appropriate modes of inquiry. They also provide stepping-off points for students to engage in meaningful discourse with their peers about particular activities or evidence. These hints are intended to help students develop an integrated understanding of the subject matter by encouraging them to produce personal explanations (e.g., Chi, Bassok, Lewis, Reimann, & Glaser, 1989). Figure 3 shows a screen-shot of the on-line help facility, with Mildred administering her special “brand” of cow-guidance.

Based on field observations and analysis of software use logs, the guidance software is currently being re-designed so students can write notes about their activities or the evidence they are reviewing. Students currently write similar notes in response to sentence-starter "prompts" in the word processing documents associated with activities. The revamped Mildred will allow students to access hints specific to the prompts more easily, and to revise their previous prompt responses.

- *The KIE SenseMaker*

Within the past year we have designed, developed, and tested a new software application called SenseMaker (see Figure 4) which allows students to organize the entire set of evidence associated a project. The SenseMaker software allows students to work with and construct conceptual arguments about the scientific evidence associated with KIE projects.

SenseMaker provides students with a means of organizing or grouping evidence into conceptual frames and to produce structured arguments or critiques (see Figure 4). The resulting SenseMaker document represents students’ inquiry and their scientific understanding. It can be used to encourage individual reflection, or alternatively, as a means for different student groups to share and compare the approaches they have taken with the evidence and project. SenseMaker arguments can be easily shared over the Web.

- *The SpeakEasy Discussion Tool*

An important component of the SKI framework involves enabling and orchestrating productive social interactions in the classroom while guarding against situations that reinforce gender stereotypes or status effects (Linn & Burbules, 1993). Students can productively exchange alternative perspectives and effectively collaborate only when they respect each other. Within the equitable social arena defined by KIE, students share, reflect upon, and refine their scientific understanding as a group. They can also participate in on-line discussions as part of KIE, where many of the same social norms and benefits are present, and inhibiting social factors are sometimes alleviated. Building on our own prior research with classroom discussion tools (Hoadley and Hsi, 1996), we have developed an exciting new Internet discussion tool known as the SpeakEasy (see Figure 5), where students participate in structured discussions about topics relevant to specific KIE projects.

Electronic discussion tools can have several advantages over classroom discussion in supporting productive learning conversations in science. In prior research with a predecessor to SpeakEasy called the Multimedia Forum Kiosk (which differed primarily from SpeakEasy in that it was not implemented on the Internet), we found that such tools enable equitable learning opportunities in scientific discourse: generating explanations, revising ideas of others, and asking questions. Studies compared gender differences in participation between class discussion and electronic discussion, and also examined three different styles of electronic discussion: anonymous, name-attributed, and name-attributed with authority participation. Results indicate that in all discussions, 78% of the students contributed in electronic discussion compared to only 15.3% participation in class discussion. Females participated more than males in electronic discussion, and less than males in classroom discussion. And females report feeling less stifled when participating in an electronic medium where anonymity is an option. All electronic discussions were characterized by high levels of scientific conceptual content, elaborations, and question-asking; students generated a repertoire of models for phenomena, asked content-focusing questions, and provided causal explanations. We have built upon the success of the Multimedia Forum Kiosk in designing its Internet version, called SpeakEasy. Figure 5 shows a screen-shot of a SpeakEasy discussion.

- *The Student Knowledge Integration Planner and Profiler (SKIPP)*

The Student Knowledge Integration Profiler and Planner (SKIPP) is another development. It has two primary parts: an activity planner and a student profiler. Thus far, work has been concentrated on the activity planner portion of SKIPP.

The activity planner is used to manage a set of KIE projects, each of which has associated activities, which in turn have associated documents and guidance for students as they work on the project. Each project also references a list of relevant and appropriate evidence. Within the activity planner, teachers and other project developers can design their own projects or modify existing projects. KIE projects can be easily imported and exported from the SKIPP, allowing projects to be exchanged over the Net through a curriculum library. Projects are currently designed and modified by project developers using the activity planner within SKIPP, and SKIPP is undergoing continual refinement as a result of feedback from these users.

The student profiler will keep track of the projects and activities each student has completed, as well as the evidence they have seen. The student profiler will also provide an entry and storage location for student interests, preferences, epistemological beliefs, and knowledge about the scientific material. This information will then be used to allow projects and activities, as well as feedback, to be customized to particular student needs using the KIE On-Line Guidance. Research is currently underway to identify ways in which this student profile information can most effectively foster student learning.

# • KIE PROJECTS

## • *Overview*

To make KIE effective for science, projects adhering to the SKI framework are needed. As mentioned, three types of projects which lend themselves to Scaffolded Knowledge Integration are: *design*, *critique*, and *theory comparison*. We have designed and constructed several new KIE projects of this nature, including testing and revision in a classroom where students are actively engaged in curriculum dedicated to our Knowledge Integration approach. Doug Kirkpatrick, a middle school master science teacher, has worked with our team as a research collaborator for more than a decade, and has played a vital role in identifying, refining, and putting into practice KIE projects.

The classroom consists of an eighth-grade physical science class where students work collaboratively on computer-coordinated laboratory exercises in topics of heat, light, and energy. This classroom context provided the perfect setting for trial and refinement of KIE projects. Projects could be designed to compliment existing curriculum. A typical KIE project will consist of several different activities, such as authoring, review and critique of Internet evidence, design, SpeakEasy discussions, and SenseMaker activities.

## • *Light Projects*

In order to synthesize and apply the principles of light detection, scattering and conservation, we have developed a project in which students make use of Internet evidence to *compare* two different theories of light: that it dies out eventually; and that it continues forever until it is absorbed. In this project, students working in groups state their initial opinion on the debate, and then survey a variety of KIE evidence items (from the NED) which they interpret as supporting or contradicting their own views. During their survey of evidence, they receive guidance on demand from the Knowledge Integration Coach, which provides cognitive and procedural hints on the activity as a whole, and the interpretation and use of specific evidence items. Next they integrate the evidence they've gathered and formulate a scientific argument supporting one of the two theories. This is accomplished in the SenseMaker application by sorting the evidence according to collaboratively defined "argument frames" (e.g., "supports Light Dies Out"; "supports both theories"; etc.) Students also brainstorm additional ideas, adding their own personal evidence items to their argument. The class also participates in a SpeakEasy discussion about how the evidence can be used to support the two theories. Finally, each group of students prepares a final statement of opinion, including supporting evidence for their chosen position (which can also include evidence to contradict the opposing view). These final arguments are presented to the class for peer review, and can even be published on the Web.

- *Thermal Events Projects*

Two other KIE projects provide students with opportunities to *critique* Internet evidence and its use in scientific argument. The first of these projects is a simple two-day project in which students collaboratively survey a set of NED items that were drawn from existing Web information. These are all Web sites which deal with the concept of passive solar home construction, and students are asked to articulate questions they are left with after observing the evidence. They are also asked to rate the evidence for its usefulness and validity. In another such project, students critique various theoretical claims which are supported by NED evidence items presented on the Internet. The claims are designed so that they require students to apply recently learned science principles concerning energy conversion, and then critique the validity of the evidence (including its source and methods), and the extent to which the evidence supports the claim. In both of these projects, students participate in SpeakEasy discussions about topics relevant to the project goals.

Another KIE project developed this year requires students to *design* a comfortable house for the desert, based on what they have learned throughout the semester's curriculum. The students begin by creating (collaboratively) an initial house design, and then proceed to survey NED evidence designed to show differences between three types of home construction: wood, adobe, and straw-bale. Students then conduct a Web search, using prototype Web searching tools (which combine existing search engines with scaffolded searching interface tools) to find relevant Web information relating to their design. Several opportunities are provided for students to revise their initial design, and they are encouraged to include discussion of relevant science principles (such as insulation, conduction, reflection of light, etc.). In this project as well, students participate in a

SpeakEasy discussion about the relative merits of the various materials and construction designs. They conclude the week-long project with a final design report, which can be published on the Web if so desired.

## • CLASSROOM RESEARCH

In addition to providing students with valuable opportunities for knowledge integration, these projects have offered us an important means of addressing research questions relating to the nature of student arguments, the use of evidence in critique and design, and the qualities of appropriate guidance, to name a few (all of which relate to a better understanding of how to implement the SKI framework within the KIE software and curriculum). In this section, we will provide short discussions of a variety of research projects which have been carried out as the KIE classroom participated in the projects described above. Results from this research are relevant to the general understanding of conceptual change in the science classroom (particularly, as it relates to the theoretical framework of SKI), as well as to the trial and refinement process involved in making KIE more and more successful as a learning environment.

### • *Comparing theories: How far does light go?*

Theory comparison activities help students distinguish and integrate ideas about scientific phenomenon. Using KIE, students compare two views of light: Does light go forever unless absorbed, or does light simply die out? Students participating in the "How Far Does Light Go" activity gain more integrated, useful, and cohesive understanding of the nature of light. These students also become adept at critiquing evidence in various media formats including films, photographs, and persuasive speeches. They have the opportunity to revisit these complex questions when solving everyday problems like surviving in the wilderness. In addition, the activities prepare students to effectively evaluate diverse materials they might encounter on the Internet and to participate in scientific conversations with a critical eye. Philip Bell asked several questions of about students' use of evidence, as well as the nature of their arguments during two semesters of trials with this project. Following are brief reviews of his research.

- <u>Eliciting Students' Conceptions of Light Using a Networked Database</u>

As part of a debate project on the nature of light, students investigated a set of scientific evidence from the Internet (see Figure 2) and constructed arguments for the theoretical positions. An analysis was performed which focused on the light conceptions students were using in their explanations of how the evidence related to the debate. Students expressed their conceptions as they engaged in sense-making activities with the Internet evidence associated with the debate, and were found to use a broad range of explanatory models for light. Students also used the SenseMaker argument software and the SpeakEasy discussion software to distinguish among their ideas and refine their models.

- Scaffolding Perspective Taking

It has been reported elsewhere in the literature that observation is a theory-laden process. Indeed, students often have difficulty seeing evidence from conceptual perspectives other than their own (Gunstone, 1992; Strike & Posner, 1992). We have been researching how we can scaffold the perspective taking process for students so that they can explore a variety of alternatives and engage in conceptual change. One instructional approach we have been investigating asks a subset of students to defend the theoretical position they had *not* selected as most resembling their own personal belief at the start of the activity. In other words, some students were asked to defend a position other than their own. Our findings show that this instructional approach encourages students to explore a conceptual alternative to their own position during the course of the project.

- Evidence Representation—The Evidence Isomorph Study

Will Internet access to multimedia documents change science learning? What are the cognitive effects of representing information using multimedia technology? To answer these questions we contrasted text and multimedia isomorphs of scientific evidence in the context of the How Far Does Light Go project. Observing students' theoretical accounts of the evidence, we found significant differences in the ways that students interpreted text and multimedia evidence. They often reported that the text version of a piece of evidence supported a different theory than the multimedia version, and tended to connect a *broader range* of scientific ideas to multimedia evidence than to text evidence. In spite of making these broader connections, however, students were *not* found to associate more productive scientific ideas to the multimedia evidence. The results suggest guidelines for cautiously incorporating multimedia into science instruction.

From an instructional perspective, it may be appropriate to incorporate multimedia cautiously given the representational effect described in this research. Multimedia representations may not have the expected effect on learning compared to that of corresponding text representations of similar phenomena. At certain points of instruction, however, it can be beneficial for students to consider a repertoire of ideas to help determine which are more productive, flexible, and more coherent with their prior knowledge (Linn et al., 1994). Results suggest that multimedia instructional materials may be useful in eliciting a broader range of conceptions from a group of students.

- *Advance Information: How do we help students get the most from complex evidence?*

Students exploring KIE evidence on the Web may often become confused by long or complicated Web sites, or perhaps their attention will become focused on tangential aspects of the evidence. They may also ignore important information about the author or source of the Web evidence (e.g., whether it is first-hand information from a credible source — or not). Generally, students may profit from having some "advance organizers" about the content, structure, and source of a piece of evidence before they survey it. Because of the structure of the NED (Networked Evidence Database; see Figure 2), each piece of KIE evidence contains a "NED page" (discussed above), where such advance information can be placed. Thus, the student who selects a certain piece of Web evidence will first arrive at the evidence's NED page, where she will receive some preliminary information, and then follow a link from that page to the actual Web site where a piece of evidence resides. James Slotta has explored an interesting research question concerning how much, and what types of advance information are most beneficial to students.

In a short KIE project designed to familiarize students with KIE, and allow them to critique evidence concerning passive solar architecture, we manipulated the information presented on the NED pages of the evidence they surveyed. While all 152 students who performed the activity received some information on the NED pages of the evidence, roughly three-fifths of them received NED pages which included some additional content. Three specific types of advance information were included: *summary* (i.e., a brief overview of the Web site's content) *procedural tips* (i.e., how to use the Web site), and *strategic guidance* (i.e., things to keep in mind while reviewing the Web site). For each piece of evidence, one or two sentences was written for each of these three types of information, resulting in a single short paragraph that was added to the NED page. Students who did not receive this advance information still had access to it on demand from the KIC guidance files for the evidence. The question was, to what extent does possession of this advance information facilitate students' ability to effectively critique the evidence?

The task performed by the students in this project was to survey each piece of evidence and generate three questions about it that related to the thermal science aspects of the evidence. Students also rated each piece of evidence for usefulness and credibility. Student responses were analyzed for differences between the two groups, and some interesting effects of advance information were observed. For some of the evidence, there was no effect whatsoever: student responses from the two groups looked completely identical. For several of the evidence items, however, there was a noticeable effect of the advance information.

In these cases, students who received the advance information were more critical of the evidence, assigning lower credibility ratings. We then took the questions generated by students for these evidence items and graded them according to (a) their focus on specific details of the evidence, (b) their relatedness to student knowledge, and (c) their relevance to the evidence content. Using a composite measure derived form these grades, we found that students who received the advance information as part of their NED pages clearly outperformed those who did not.

These preliminary results suggest that it is possible to have a positive effect on students' ability to understand and evaluate Internet evidence by providing only slight amounts of advance information. It is important to remember that students who did not receive the information in advance still had access to it through the KIC guidance for the evidence. Thus, the positive benefit was derived from having some coherent overview, procedural, and strategic information about the evidence "up front." The NED page provides a fortuitous means of providing this information for all KIE evidence, and future research will explore the composition of effective advance information in greater detail, as well as the effect of advance information in different types of projects, and its relation to the guidance KIE provides during the students' survey of the evidence.

- *Exploring Student Discussions: What keeps your lunch cold?*

KIE activities help students identify and analyze alternative explanations for complex phenomena. One KIE approach, the SpeakEasy, engages students, teachers, and natural scientists in expanding the repertoire of explanations for a scientific event and distinguishing among them. As a group, participants contribute alternative interpretations of complex questions such as "What keeps your lunch cold?" SpeakEasy structures the discussion, guiding contributors to indicate when their comments reinforce, extend, or contradict those already in the discussion. SpeakEasy encourages students to reflect and read comments by others before adding comments of their own. As a result, students in a SpeakEasy discussion are more likely than those in a classroom discussion to recognize when their peers disagree with them.

SpeakEasy permits anonymous or personalized comments. Discussions, including electronic discussions, often silence female students and privilege teachers. Chris Hoadley and Sherry Hsi have found that female participants in a SpeakEasy discussion contribute more when they have the option of being anonymous than when all comments are personalized (Hoadley and Hsi, 1996). Also, students tend to discuss teachers' anonymous contributions more than their personalized contributions. Teachers comment that they learn more about student views of scientific dilemmas and student methods of evaluating evidence from electronic discussions than from class discussions.

- *The Nature of Effective Guidance: "What to do" versus "What to think about"*

Research on middle school students working on large science projects in KIE indicates that metacognitive scaffolding provided through prompts improves the quality and quantity of their work. The objective of Betsy Davis' research is to develop an exemplary program of metacognitive prompts, in order to encourage principled knowledge integration. Through this research, we address two questions. First, what effects do "self-monitoring" and "activity-focused" metacognitive prompts have on middle school students' ability to develop an integrated understanding of science topics? Second, what explanation might account for differences in effects of the two types of prompts?

Two studies have investigated students' use of these two types of metacognitive prompts (activity-focused and self-monitoring). Activity prompts walk students through the important steps in the activities comprising a large science project (e.g., providing justifications or explaining decisions), while self-monitoring prompts encourage planning for and reflection on those activities. Activity prompts are found to help students complete all the pieces of a project, while self-monitoring prompts encourage students to demonstrate an integrated understanding of the relevant science topics. Further research is underway to investigate whether all students benefit equally from the two types of prompts. If they do not, we seek to determine the student characteristics that determine which students benefit more from each type of prompt. This research will also inform the best ways to incorporate these prompts into the KIE software.

- *Searching for New Evidence: How students can manage*

An important activity in anyone's experience of the Internet is that of searching for information relevant to a specific question. For scientists, locating evidence to support the decision-making process is an essential step in building an argument. While this is something that many of us do routinely, the searching activity represents an interesting and essential component of student activity that we must try to understand and incorporate into the KIE software and curriculum. Alex Cuthbert has begun this study, embracing a holistic view of the search process involving problem definition, evaluation, and knowledge integration.

The activities in which searching took place focused on topics that were revisited throughout the semester including insulation, conduction, temperature, and heat. These topics were embedded in the desert house design project, which consisted of surveying and critiquing Internet evidence, discussing the merits of building materials, searching the Internet for additional pieces of evidence, and designing a house for the desert that would stay warm at night and cool during the day. In January and May 1996, approximately 250 students completed the project, which included an Internet search activity. The search environment used in this KIE project was designed to provide students with dynamically updated access to the sites, ratings, and comments from students in their class as well as from the previous semester. In addition to addressing the broad questions relating to how students use search in a knowledge integration activity, we studied how access to other student-located sites affected a student's own search process. Specifically, we were interested in scaffolding students who had difficulty locating useful sites.

The time needed to locate relevant information on the Internet makes searching a questionable practice for most middle school classrooms. However, for individual or small-group projects, access to additional information may help students develop a feeling of ownership, distribute expertise, and lead to the acquisition of valuable research skills. The definition of the problem is of primary importance, because it contributes to students' perceptions of which pieces of evidence are interpreted as relevant.

The students who participated in this project did benefit from visiting additional sites, as can be seen from their incorporation of ideas used in those sites in their final reports. However, the students did not exhibit a high degree of sensitivity to alternatives and did not have a well-articulated strategy for sorting through evidence. The pattern of searching activity that emerged in the first semester was more characteristic of perceptual search patterns directed by the stimulus of the display rather than the logical deployment of a systematic search strategy. These findings guided the redesign of the activity for the Spring 1996 implementation of the project. Besides reworking the search environment to facilitate sharing of resources, the project was broken into several distinct stages (preliminary design, surveying evidence, synthesizing evidence, discussing evidence, Internet search, heat flow analysis, and design report) which might result in making students' search activities more deliberate. We are currently analyzing the effect of this more structured approach in terms of how generative the activity was and how well it encouraged the integration of knowledge and the articulation of applicable scientific principles.

## • THE KIE LIAISON PROGRAM

The basic role of a KIE liaison is to contribute scientific or educational expertise while helping to develop KIE projects. The KIE Web site[1] describes our interest in

[1] The URL of KIE Web site is: http://www.kie.berkeley.edu/KIE.html

recruiting Internet liaisons and the requirements that we hope liaisons will meet. As a result, we are forming partnerships with science laboratories, natural scientists, and science education projects. This year, we have initiated relationships with several new liaisons, resulting in new projects, new classrooms for use with KIE, and new possibilities for future collaboration. These first liaisons will provide a research foundation for many such relationships in the future.

Physicist/astronomer Bruce Grossan is developing a KIE project in which students learn about the thermal properties of everyday cups. While surveying evidence about cups, students will gain an integrated understanding of concepts in thermal science (e.g., heat capacity and conductivity). They will then apply what they have learned from the evidence to the task of designing cups for specified purposes.

Lawrence Berkeley National Laboratory is developing a KIE project on air quality in collaboration with the KIE project. The project includes a set of Web evidence, and a "low-tech" classroom data collection activity. The LBNL Web evidence has now been completely drafted, and can be seen on the Web[2]. The design of both these projects is completed and implementation work will continue this summer.

We are also pleased to have made KIE software available to another NSF-funded project, the CoVis project. This year, students participating in the CoVis project have been using the KIE SpeakEasy as part of their science discussions.

We have learned much this year about the process of collaborating with liaisons to develop KIE projects, which will be a truly important one in years to come. It is essential to understand the nature of this development process, including issues of educating the liaison about the KIE software and approach, establishing a partnership in project design, helping to create a working set of evidence, and moving through the process of testing the project in a classroom setting. All of these issues have presented us with uncharted new ground, and it has been a difficult but exciting journey (led by our liaison coordinator, Steve Adams, and postdoctoral scholar, James Slotta). We look forward to testing the two new KIE projects in classrooms this coming Fall; meanwhile we are pursuing several new liaison relationships:

- James Harrington of NASA plans to hire an intern this summer who to develop a KIE project on a topic of interest to NASA.
- Lisa Bievenue of NCSA plans to include KIE in a workshop on the Internet for teachers this summer.
- Lynn Kopf is preparing a proposal to develop a KIE unit on earthquakes as part

[2]http://www.lbl.gov/Education/ELSI/ELSI.html

of a Master’s project at San Jose State University. Lynn is a teacher at a school in Union City and is already using KIE in her classroom. In addition to interactions with the KIE team, she will be consulting with Dr. Michael Smith of the University of Delaware, who is a domain expert in earthquakes, and is also interested in the KIE project.

Finally, we are actively pursuing additional KIE liaisons. In the San Francisco Bay Area, we have consulted with the Science Education Partnership, which is a collaboration between San Francisco State University and San Francisco schools. Our contact, Paul Herzmark, has expressed interest in using the SpeakEasy as a way for participating scientists to have discussions with students. We are also continuing discussions with science education projects in several other states, including Texas, Illinois, Florida, Tennessee, and Virginia, who have all expressed interest in collaborating with us.

## • SCHOOL SITE PARTICIPANTS

Since the outset of this research, we have been committed to seeing the Knowledge Integration Environment applied in other school settings, and disseminated as widely as possible. Our aim is to provide teachers with a powerful tool for bringing Internet-based learning activities into their classrooms, assuring the effective use of integrated science learning activities. Publicity from our KIE Web pages has resulted in numerous requests for information, with many teachers downloading our software and exploring KIE projects for possible use. Locally, we have made contact with several teachers, thanks to our teacher outreach coordinator, Doug Clark. Last year, Doug initiated a number of methods for locating schools to participate in Knowledge Integration Environment activities, resulting in several exciting opportunities this year to actually explore the use of KIE in new classrooms.

We began working on the KIE project at James Lick Middle School in San Francisco during the last week of October (see Figure 6). James Lick is a demographically diverse urban middle school with a large Latino constituency. According to the teachers, the school is not a school of choice for parents, so the students at the school tend be those with parents who didn’t make a choice, and thus ended up at James Lick by default. The student body of six hundred students represents almost fifty elementary schools, so there is little homogeneity in terms of the preparation that they have received. Reading levels at the school are very low, but the teachers and administrators have a very positive energy, and are interested in change.

We installed the KIE materials on computers in the library, and trained the Americorps technology coordinator in its use. The coordinator ran eighth grade science students through the KIE "How Far" unit on light while Doug Clark observed. For two months, students and the coordinator discussed the evidence, conducted auxiliary research on supplemental topics, debated, and made presentations to classmates, the principal, and other teachers. The results and process are considered a success by the coordinator, teacher, and students, and KIE software has now been installed in the teacher's classroom for independent student work. In working with James Lick, we also explored several important questions of our own relating to the effective dissemination of KIE, including:

- How can we best facilitate the implementation of KIE into an urban school?
- What changes need to be made to the software and to the preparation procedures?
- What strategies would seem strongest for an urban setting?

The SKI framework and KIE have been designed to support all learners, and running this project at an urban middle school was the first step toward proving that KIE has been successfully designed in service of this goal. The SKI framework played important roles in making the material accessible for these students, particularly the component which focuses on providing social supports for learning. In fact, these social supports for learning seem to play a more crucial and integral role for the students at James Lick than for the students in Walnut Creek. Figure 6 shows a photograph of students working with KIE at James Lick Middle School.

Beginning in March, four classes of sophomores from Logan High School (see Figure 7), a large urban school in the Bay Area, used a KIE project in which they compared different theories of dinosaur extinction. Approximately four thousand students attend Logan, whose student body is evenly distributed among African-American, Hispanic, Euro-American, and Asian-American ethnicities. Logan does not track in science, so that all students take the same freshman and sophomore classes. This study was conducted with the sophomore integrated science course, which follows the development of the earth. One-hundred-twenty-six students worked in pairs in their classroom, debating two different theories of what caused the dinosaurs' extinction. In the course of the project, they surveyed considerable evidence, and wrote letters critiquing the strong and weak points of each theory. The teacher was very impressed with KIE, and will be using our software and curriculum next year. She has also volunteered to become a liaison in order to construct another project for us.

In May, another teacher at Logan also used KIE with four classes from the sophomore integrated science classes. He also worked with the dinosaur extinction unit, but chose the computer center for his venue so that all of his 127 students could work on the project at the same time. The KIE observer, Doug Clark, demonstrated the software and unit for the teacher, who then conducted the classes for the students. This teacher also found KIE to be useful, usable, and impressive, and hopes to use KIE in the fall semester of the coming school year. We will apparently have the great opportunity to run the KIE "How Far" project with as many as five teachers and seven hundred students this coming fall. Figure 7 shows two photographs of students working together at Logan High School.

Over the past year, we have conducted three teacher enhancement workshops. Two workshops introduced teachers to issues of using the Internet in education. The third workshop, attended by over thirty teachers, was a hands-on, intensive introduction to the KIE software and curriculum. Teachers reported being very receptive to the KIE approach of using the Internet in science classrooms. We are in the process of planning a summer institute for teachers wanting to incorporate KIE in to their classrooms and develop new KIE curriculum projects.

## • CONCLUSIONS

During this project year we have substantially refined KIE software, developed additional KIE projects, and also tested software and project effectiveness in the classroom.

To develop new KIE projects we worked closely with KIE liaisons from a broad range of institutions. This undertaking has proven successful and will benefit from further refinement.

To test KIE projects, we have collaborated with a variety of school sites. The project is encouraged by proof-of-concept research that demonstrates that KIE activities help students understand concepts in the area of heat and light. In addition this research demonstrates that students can interpret complex Internet evidence and make sense of information from a variety of sources that vary in their validity.

The KIE project follows a trial and refinement process in creating and improving software. Trial and refinement is guided by the Scaffolded Knowledge Integration framework. Refinement of the software provides insights for improving the framework. This year we have emphasized two aspects of the framework. First, we have addressed the social nature of learning. Using SpeakEasy and its predecessors, we have gained understanding of mechanisms for supporting student discourse. Also, we have demonstrated how engaging in scientific discourse improves student learning. Equity of opportunity to contribute to class discussion and learn from peers is a benefit of these environments.

In addition, the project has explored techniques for making the thinking students engage in more visible. These have included software tools such as SenseMaker that allow students to represent an argument and modify the warrants for their conclusions in a graphical representation. We have also explored making thinking visible in the context of looking at how students respond to video clips and photographs as evidence for scientific reasoning.

A third aspect of the Scaffolded Knowledge Integration framework, encouraging reflection, has been explored by studies of student response to prompts. In this area we have gained considerable insight into how students use prompts. We also found that there are substantial differences with regard to individual student disposition towards using prompts.

The project has pilot tested KIE activities in a variety of different schools and encountered the usual challenges for such work. Inevitably, logistics of using technology in the classroom end up demanding more time and energy than anticipated. Nevertheless, in every case, teachers have complimented the work and students have gained understanding. Further refinement of classroom implementation will occur in the future.

The Knowledge Integration Environment is a work in progress. This year's progress offers support for the Scaffolded Knowledge Integration framework, evidence that the preliminary version of the software can improve student learning and suggest directions for further refinement. The project has gathered a broad range of evidence to guide these refinements and will revise and expand the software and test the materials more broadly in the coming year.

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## • PROJECT PRESENTATIONS

**1996**

Marcia C. Linn
*Technology and Instruction*
American Education Research Association Annual Meeting
April 12, New York, NY

Philip Bell and Elizabeth Davis
*Designing an Activity in the Knowledge Integration Environment*
American Education Research Association Annual Meeting
April 10, New York, NY

Chris Hoadley and Sherry Hsi
*A Theory of Collaborative Networking in the Science Classroom*
American Education Research Association Annual Meeting
April 10, New York, NY

Marcia C. Linn
*Views on Affirmative Action in the 1990's: What Works? Technical Perspectives*
American Education Research Association Annual Meeting
April 9, New York, NY

Elizabeth Davis
*Metacognitive Scaffolding to Foster Scientific Explanations*
American Education Research Association Annual Meeting
April 9, New York, NY

Marcia C. Linn
*The Knowledge Integration Environment as a Prototype*
Computer Science Department
University of Colorado at Boulder
March 21, Boulder, CO

Marcia C. Linn
*What Makes Science Hard?*
Center for Advanced Study in Behavioral Sciences
February 28, Stanford, CA

Marcia C. Linn
*What Constitutes Lifelong Science Learning?*
Stanford University
February 14, Stanford, CA

Christopher Hoadley and Philip Bell, coordinators
*Authoring for the Web: Teacher Workshop*
Foothill Middle School In-Service Teachers
February 9, Walnut Creek, CA

**1995**

Philip Bell
*The Knowledge Integration Environment: Theory and Design.*
Presentation to the Kids as Global Scientists Research Group
University of Colorado at Boulder
December 20, Boulder, CO

Elizabeth Davis and Philip Bell, and the KIE Research Group
*The Knowledge Integration Environment: Engaging Middle School Students in an Exploration of Evidence on the Net*
Exhibit presented at Computer Supported Collaborative Learning Conference
October 18, Bloomington, IN

Philip Bell, Elizabeth Davis and Marcia C. Linn
*The Knowledge Integration Environment: Theory and Design*
Computer Supported Collaborative Learning Conference
October 18, Bloomington, IN

Marcia C. Linn
*"Turn Up the Heat The Baby Has a Termperature" or How Do Students Learn Thermal Concepts?*
Invited session, Semi-Annual Meeting of the American Association of Physics Teachers
August 9, Spokane, WA

Philip Bell
*Middle School Students' Understanding of Light as Seen Through Their Exploration of Evidence*
Invited session, Semi-Annual Meeting of the American Association of Physics Teachers
August 9, Spokane, WA

Sherry Hsi
*Do 8th graders reason like physicists? Learning thermal-concepts through computer-supported scientific discourse*
Invited session, Semi-Annual Meeting of the American Association of Physics Teachers
August 9, Spokane, WA

Doug Clark, Philip Bell, and Doug Kirkpatrick, coordinators
*Knowledge Integration Environment K-12 Teacher Training Workshop*
In conjunction with the Electrical Engineering and Computer Science Department, U. C. Berkeley
June 28, Berkeley, CA

Marcia C. Linn
*Cognition and Technology*
Technical Education Research Centers Conference
July 26, Boston MA

Marcia C. Linn
*How Can We Increase the Participation of Females in Mathematics and Science*
Lawrence Livermore National Laboratory Women's Association General Meeting
July 13, Livermore, CA

Marcia C. Linn and Eileen Lewis
*Tools for termless learning*
National Educational Computer Conference
June 17, Baltimore, MD

Marcia C. Linn
*Technology and Instruction: Lessons Learned*
King's College
June 2, London, England

Marcia C. Linn
*Science Education and Technology: Current Trends, Historical Antecedents*
Weizmann Institute
May 23, Tel Aviv, Israel

## • PROJECT PUBLICATIONS

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