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Educational Applications of a Networked Communal Database

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In this article we present results from classroom uses of Computer Supported Intentional Learning Environments (CSILE) which has functioned as a central, cross-curricular knowledge medium in four elementary classes, spanning Grades 1 through 6. Discussions of the theory and design principles guiding CSILE development have been provided elsewhere (Scardamalia & Bereiter, in press-a; Scardamalia, Bereiter, McLean, Swallow, & Woodruff, 1989). Here we want to focus on one major characteristic of CSILE, its student-generated communal database, and to discuss findings that relate to its uses and effects. The communal database is central to CSILE's design, but we believe it can play an important role in any educational software system intended to foster inquiry, intellectual discourse, and social construction of knowledge.

There are a number of experiments in which classroom computers play an important role in students' knowledge-related interactions. Educational experiments reported in the 1980s were based on computer conferencing (Black, Levin, Mehan, & Quinn, 1983), electronic mail (Hiltz, 1988; Levin, Riel, Rowe, & Boruta, 1985; Riel, 1983; Sayers, 1989), interactive writing programs making use of dialog journals (Staton, Shuy, Peyton, & Reed, 1988), and letters (Heath & Branscombe, 1985). The use of networks for realtime written interaction followed, with projects such as the Electronic Networks for Interaction (ENFI). Batson (1988) described ENFI as:

> *off-the-shelf, local-area networks and a "deluxe chat" utility that allows online group written "conversation ": only a bunch of computers people use to "talk" to each other... ENFI allows for simultaneous responses to a question or comments on a topic because everyone can write at the same time while the program queues submissions and displays them in the order they are "sent " (pp. 32, 33)*

Newman (in press) explains that access to stored material has taken precedence over direct student-to-student communication in many educational applications:

> *The technologies of central interest are local area networks (LANs) within the school. The group members do not normally communicate with each other via this network. Instead, they use the LAN to access technology*

resources, to communicate with the teacher and other groups, and to store and access group products.

An example is Earth Lab, which provides central storage of information, with filing facilities making it possible for students to create databases accessible from any computer in the school (Newman & Goldman, 1987). Collins and Newman (1991) extended this basic framework to provide students with research notebooks for recording ideas, questions, and results of classroom investigations.

Telecommunications are expanding LAN horizons. Systems such as the National Geographic Kids Network use long-distance links to contribute to national databases. Students from distant places enter data, and then the full data set is downloaded to individual classrooms. Other examples based on telecommunication facilities include Apple Global Education, the AT&T Long Distance Learning Network, and the TERC Star Schools Project.

If one attempts to provide all the necessary knowledge-sharing functions with commonly available software, one ends up with a complicated package: shared files for group access, communication software to notify others of new material and to link databases, database software for systematic retrieval of organized information, and text and graphics software for students to produce their own material. In CSILE, we have tried to provide for all these functions through one integrated piece of software that stores all student productions, text or graphic, in a single database to which all users have simultaneous access. It can function as a private notebook (by designating notes as "private" when they are stored). It can function as a multiuser database of public notes, with facilities for retrieval by keywords and other note attributes. It can function as a communication medium through its commenting, importing, exporting, and notification facilities. And it can function as a medium for collaborative knowledge construction, through features such as hierarchical note-linking and coauthoring capabilities.

To date, CSILE has been used for units in science, mathematics, history, social studies, geography, biology, physics, and art, and is central to the language arts curriculum including reading, writing, spelling, dictionary, and vocabulary use. Because it is central to so much of the work in each classroom, teachers have needed, and in turn, have helped us design a variety of additional features to support its everyday use. These include tracking systems for constructing profiles of individual students' work, a specially designed spelling checker that uses a student-developed communal dictionary, and portfolio facilities so that students can flag and display their work for purposes of self-assessment and teacher review. In this article, however, we shall concentrate on the communal database component of the system as it has been used in two Grade 5-6 classes for the past 5 years, and in Grade 1-2-3, and Grade 4-5 classes for the past 2 years.

Although it is possible to achieve some of the functionality of a communal database through the use of shared files or by having students work in teams or take turns with a single-user database, a database system needs the following capabilities in order to function as a communal medium in schools:

1. Simultaneous access, including authoring access, by multiple users.
2. Preservation (but not necessarily display) of author identity of database entries.
3. Protection of database entries from deletion or modification by other than authors or collaborators.
4. Provisions, in the assignment of keywords or other identifiers, to minimize accidental or idiosyncratic variations that make retrieval difficult.
5. Provisions for commenting on others' entries and notification of authors when comments have been made on their entries.

CSILE's database is designed with these requirements in mind. The elements making up a CSILE database are individually authored notes, which in current versions may be of two types, text or graphic (we will soon add coauthored notes and additional types such as video and audio). In the communal context of CSILE's database, all of the student's notes are public unless the author specifically chooses to have the note stored as a private note or as an anonymously written note in the public database. Student generated keywords for notes are compiled in a common keyword list, arranged alphabetically. We are currently experimenting with facilities that enable students to identify relevant keywords already used on other notes and to develop domain vocabulary lists cooperatively. Notes from different content areas and authors all go into the same database; there are not separate databases for different curricular contents.

Only the author can modify a note, but students can interact in several ways. A student can produce a note that is attached as a comment to another student's note, or can add keywords to another student's note. There is automatic notification to authors when comments are added. With graphic notes, one student can produce a graphic that is linked to a point or label on another student's graphic, thus creating a multiply authored branching tree of notes with hierarchical or zoom-in/zoom-out characteristics. To encourage such interaction, the main CSILE screen allows a student to view found notes in one window while composing comments or related notes in another.

This article is about the earliest findings from extended use of CSILE's communal database in the elementary school. We make use of experimental-control data, but it is important to appreciate that it is not possible to have experimentally rigorous controls for complex educational experiments of the sort reported. The CSILE system is evolving, so there is continual interaction among designers, teachers, researchers, and students. Some of the features that were used early on have been revised or replaced. New features have been added all along, and projected capabilities such as telecommunication links, video, and audio notes have not yet been put into classroom use. Although we do not prescribe uses for CSILE, we do meet with teachers and discuss CSILE principles and goals. For example, we discuss our ideal model for teaching, one that has students working as active agents in the construction of their own knowledge. The implication is that teachers will use CSILE capabilities in ways that support the broader principles that underlie CSILE's design. There remains, however, a great deal of latitude in how teachers incorporate CSILE into their teaching and, in turn, shape their teaching in response to what students do on CSILE. The different models of CSILE use that have evolved with the two teachers who have used CSILE the longest provide, in fact, an important subtext to this report, suggesting the range of ways that a communal database may function in classrooms. We also provide a brief overview of how the communal database is used in the early elementary grades. Significant gains on tests of various sorts show educationally productive activities associated with all uses of the system. Analyses also show significant differences in effects associated with different models, suggesting guidelines for educational uses of communal database systems and needed software enhancements.

INSTALLATIONS AND DATA SOURCES

Current versions of CSILE are written in C and run on a UNIX platform. The two configurations relevant to findings presented here are the following:

1. ICON configuration. Sixteen Unisys ICON I microcomputers are linked to two 64-megabyte fileservers. The ICON I is a school-oriented microcomputer with color graphics, a trackball performing the functions of a mouse, and 512K of RAM. It is specifically designed for networked installations and uses a proprietary subset of UNIX. In 1986 this configuration was installed in two Grade 5-6 classrooms, with 8 ICONs and a printer in each room. In 1988 this configuration was moved to serve, in a similar manner, a Grade 1-2-3 classroom and a Grade 4-5 classroom.
2. Macintosh configuration. Sixteen Macintosh IN microcomputers with RGB color monitors are linked via Ethernet to an additional Macintosh IN with a 160-megabyte hard disk, functioning as a fileserver running A/UX 1.1, Apple's version of UNIX. Each of the terminal microcomputers (8 per classroom) has 8 megabytes of RAM and an 80-megabyte hard disk. In 1988 this configuration was installed in the two Grade 5-6 classrooms, in the same manner as the ICON configuration, as described in the preceding paragraph.

CSILE has also been ported to the IBM RISC/6000 and installed in a high school, using a computer lab configuration. Because this installation was very recent, no findings have been reported.

Experimental and Control Classes

The experimental classes considered in this article are the four multigrade classes referred to in the preceding section: one Grade 1-2-3 class, one Grade 4-5, and two Grade 5-6 classes. All are in the same inner-city school serving an ethnically and socio economically heterogeneous but predominantly middle-class and university-educated population.

Mainly observational data will be reported from the two lower-grade classes, with no comparison data from non-CSILE classes. A longitudinal study is in progress, in which cognitive assessment data are collected from all classrooms, CSILE and non-CSILE, in the host school. This study will eventually make it possible to relate educational outcomes to number of years spent in a CSILE classroom. At this time, however, comparative data are only available at the Grade 5-6 level. These data come from the two CSILE classrooms and from a control classroom in another school. Because no comparable innercity classroom was available, the control classroom was selected in a suburban school, serving a more homogeneous and stable middle-class population, but with a very similar level of achievement, as will be indicated in the standardized achievement test data to be reported. Comparisons between the two Grade 5-6 CSILE classrooms also figure prominently in the results to be reported. In this regard it may be noted that assignment of students to these two classes is reported, by teachers and principal, to be random (an assertion supported by similar achievement test data for the two classes).

Instruments and Procedures

The richest source of data on educational uses of CSILE and their effects is, of course, the student-generated databases themselves. In sections that follow, we make extensive use of examples of text and graphic notes selected from these databases to illustrate particular uses, accomplishments, or problems. Although these examples are only illustrative, they are at times sufficiently remarkable that they at least suggest educational outcomes lying outside the range of what is normally observed in elementary school classrooms. We therefore consider such examples to be important heuristically. One member of the CSILE project staff has had, as a major responsibility, to keep studying the student-generated databases as they develop and to extract anything that seems, for any reason, to be worthy of special notice. Such monitoring of the databases has been the source of the examples used in this article.

Information automatically stored or derivable from CSILE notes permits elaborate tracking of students' CSILE-related activities, for example, *productivity*, as indicated by the number and size of notes contributed to the database, and *interactivity*, as indicated by factors such as the number of searches of notes by other students, the number of comments given or received, and number of linked charts. Tracking data are especially relevant to studying different models of CSILE use in the two Grade 5-6 classrooms. Comparative achievement data used in this report are of several kinds:

1. Standardized achievement test scores. Six subtests, making up the language and mathematics sections of the Canadian Test of Basic Skills (essentially the same as the California Test of Basic Skills), are administered each spring. In 1989-1990, however, these were administered in both the fall and the spring to the Grade 5-6 experimental and control classes, thus permitting a comparison of gains.

2. End-of-unit reports of "what I learned."
3. A question-asking task that required students to list questions regarding what they wonder about a topic.

OBSERVATIONS OF EDUCATIONAL USES OF CSILE

In this section we rely mainly on classroom observations and on examples drawn from student-generated databases to indicate the kinds of educational activity that a communal database appears to foster.

This section is divided into two parts. The first deals with CSILE use in the Grades 1-2-3 and 4-5 classrooms. Here we focus mainly on the youngest students, examining their rather surprising use of CSILE as a medium for knowledge diffusion. The second part deals with the two Grade 5-6 classrooms, in which rather different models of CSILE use have evolved. One model stresses individual research and production whereas the other stresses collaborative knowledge construction. In a later section we present data from tests and activity tracking showing the differential effects of these alternative ways of using a communal database.

CSILE With Young Students

It is a common observation that young children quickly learn to use complex software, even preliterate children manage to recognize menu selections and the like. Experience with CSILE in the primary grades replicates these observations, but with some interesting extensions that relate to the communal database. When children produce text notes in CSILE, these go into the public database along with other children's productions. Just to be able to find their own work again they need to learn to assign useful keywords and to construct search commands. The growing keyword list, in turn, serves as an invitation to look at the contributions of other children. The uses children make of one another's accomplishments suggest distinctive educational contributions made by a communal database, over and above the advantages that accrue when young children are provided with computer tools for creating text and graphics.

Borrowing and Adding Value to Words and Graphics

When students have electronic access to one another's work, there is an inevitable tension surrounding copying. On one hand, it is desirable for students to benefit from and build upon one another's findings, but on the other hand, there is a concern about plagiarism and overdependence on others' thinking. (Note that a similar tension exists in the world of academic publishing.) In designing future versions of CSILE, we are working on ways to ensure that copied material is identifiable and referenced; but in the version on which this report is based, children could freely copy material from other notes into their own. After discussing the copying issue, teachers agreed to promote the view that it is perfectly legitimate to copy material or use ideas from others' notes, so long as proper credit is given. Even children in the first grade have proved highly receptive to this view, have found surprisingly constructive ways to make use of copying, and have been generous in their acknowledgment of others' contributions. For example, a Grade 1 student had reportedly worked for a long time trying to spell the word *friend.* While browsing the database she saw someone had written "my friend" and delightedly borrowed (copied) the word "my", thanking the author of "my."

Figure 1 provides a striking example of a phenomenon we call "appropriating and extending." The upper picture, titled "eeeeeeeeeeeeeeeeeeeeeeek!", was drawn by a student in Grade 4. A Grade I child saw this while browsing the communal database and copied it because "It was pretty neat," retitling it "cherch. " Other first-graders copied the same picture, adding their own variations. See, for instance, "town" at the bottom of Figure 1. The child who produced "town" explained, "I added smoke, the chimney, door, windows, an extra tower, and put a smile on the moon." When asked why she copied it she said "I was looking through her file and thought this one was really good. I liked it." Children seem to look for and remember quality entries in the database. When children are demonstrating CSILE to visitors, it is not uncommon for them to show off, with evident pride, exemplary work by other students that they have discovered and know where to locate.

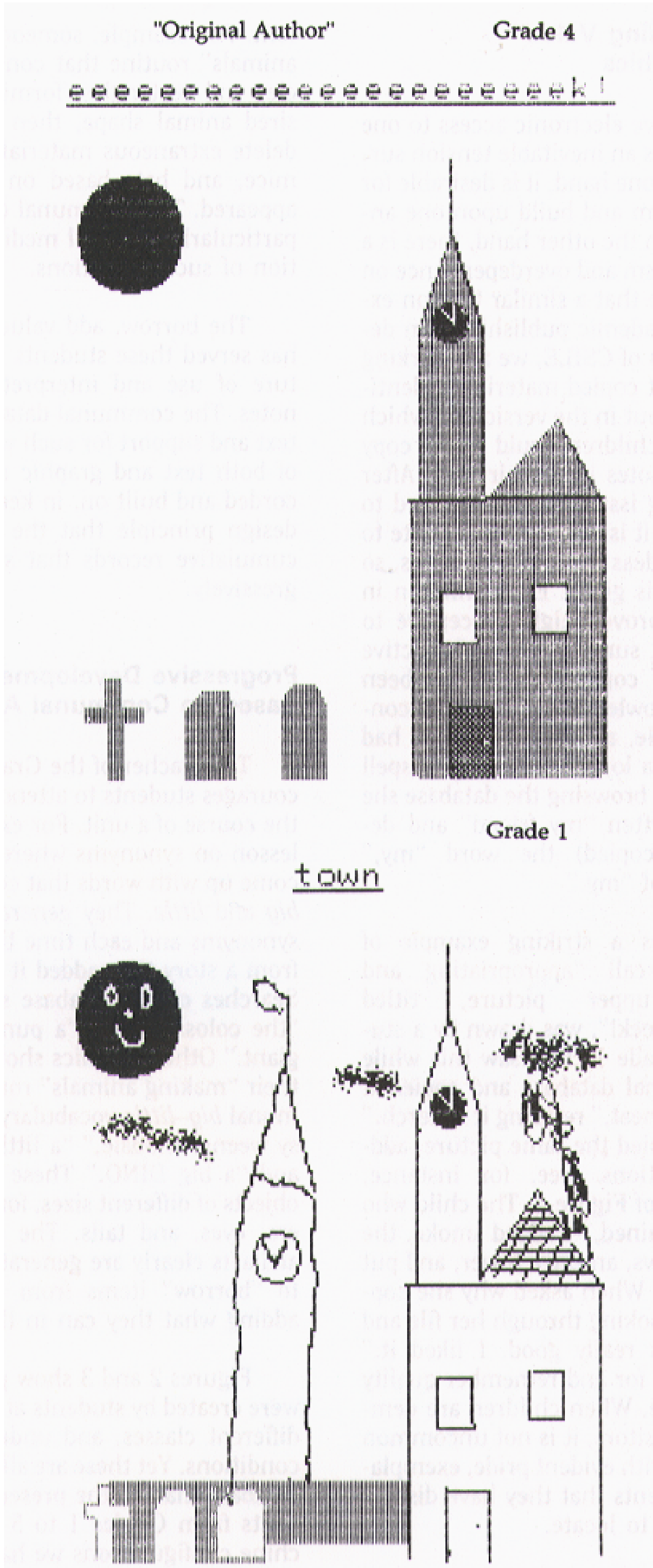


Figure 1. An example of a graphic drawn by a Grade 4 student and later copied and modified by a Grade 1 student

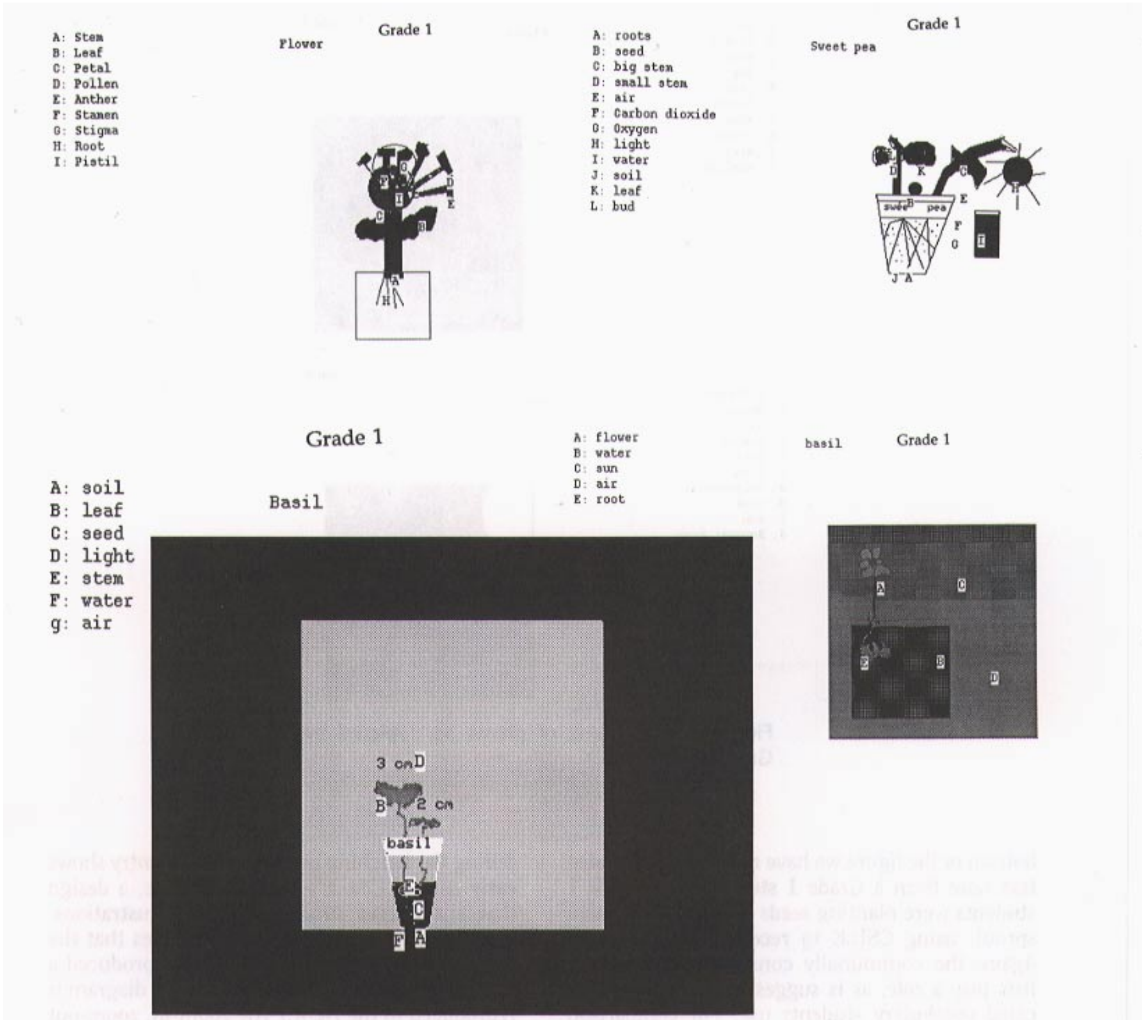
Children browsing the database will sometimes appropriate techniques rather than content. For example, someone invented a "making animals" routine that consisted of selecting circles and rectangles, forming them into the desired animal shape, then using "white out" to delete extraneous material. Snow bunnies, cats, mice, and bats based on this strategy quickly appeared. The communal database seems to be a particularly powerful medium for the dissemination of such inventions.

The borrow, add value, and credit approach has served these students well in creating a culture of use and interpretation of each others' notes. The communal database provides the context and support for such work, including models of both text and graphic material. Ideas are recorded and built on, in keeping with the general design principle that the database should hold cumulative records that students work on progressively.

Progressive Development of Ideas Based on Communal Artifacts

The teacher of the Grade 1-2-3 students encourages students to attend to vocabulary used in the course of a unit. For example, students had a lesson on synonyms where the challenge was to come up with words that could be substituted for *big* and *little.* They generated a common list of synonyms and each time they heard a new word from a story they added it to the communal list. Searches of the database show pictures such as "the colossal sky," "a puny pencil," and "a big giant." Other graphics show students combining their "making animals" routines with their communal *big-little* vocabulary list to create "a teensy weensy mousie," "a little cat," "a big whale," and "a big DINO." These routines expanded to objects of different sizes, for example, giants, towers, eyes, and tails. The communally available artifacts clearly are generative, allowing students to "borrow" items from communal resources, adding what they can in the process.

Figures 2 and 3 show plant illustrations that were created by students at different age levels, in different classes, and under different curricular conditions. Yet these are all part of the communal database that, in the present situation, links students from Grades 1 to 5 (due to different machine configurations we have the two Grade 5-6 classes on another network). All of the diagrams in Figure 2 are from students in Grade 1. At the bottom of the figure we have reproduced a related text note from a Grade 1 student. The Grade I students were planting seeds and watching them sprout, using CSILE to record what they saw. Again, the communally constructed vocabulary lists play a role, as is suggested by the sophisticated vocabulary students use. For comparison we have presented several Grade 5 entries on the same topic (Figure 3). Note that a good deal of the vocabulary used at the different grades is common. Keyword searches based on this common vocabulary will serve to cluster the work of these Grade 1 and Grade 5 students, and in turn, bring them into contact with a wider array of vocabulary and illustrations than they could obtain without the aid of a communal database. It is also empowering for young students to have their work configured with that of the older students.



Author: Grade 1
Last Change: 1990 May 1 12:00:48
Keywords: plants.

The seed has the roots and the sprout inside.
The roots collect all the water.
The stem connect to the flowesr and the leafs.
The leafs catch the sunlight. And you can eat the leafs.
The leafs give us shade.And we can rake the leafs up and jump in them. The soil has the vitamins.The light is for the plants to grow.

Figure 2. Diagrams of a seed-planting experiment drawn by Grade 1 students. Also shown is a related text note

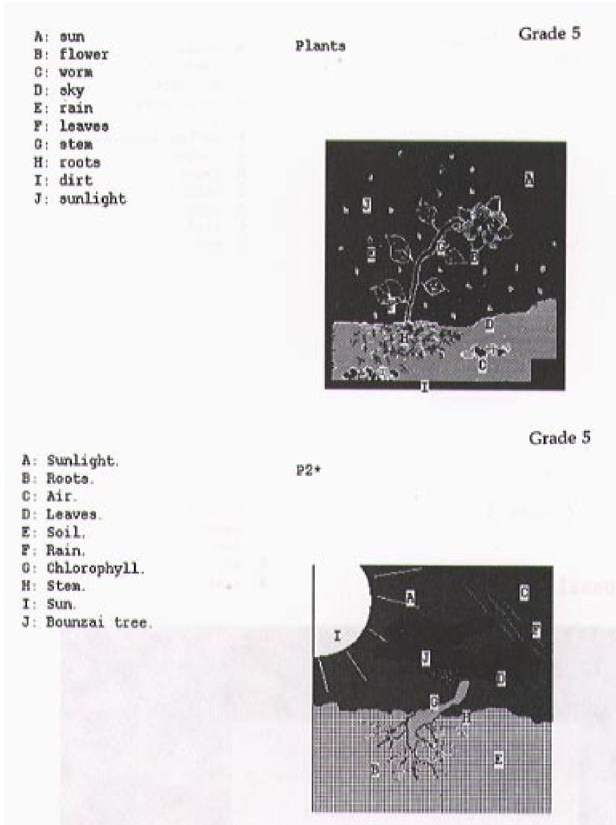


Figure 3. Diagrams of plants as depicted by Grade 5 students

An additional facet of the communal database is suggested by the illustrations in Figure 4. In this case students hatched eggs in class and their drawing, labelling diagrams, and compiling of a common word list was part of the record keeping during the hatching process. The top entry shows early uses of CSILE's zoom-in feature, a design that encourages students to link illustrations. The plus sign next to "D:egg" indicates that the student "zoomed in" to the egg and produced a diagram linked to it. (The linked "egg" diagram is reproduced to the right.) The zoom-in, zoom-out feature was designed to help students think in more relational terms, including part-whole, causal, and explanatory relationships. CSILE allows students to create "zoom-in" notes attached to labels on other students' notes, thus permitting collaborative development of a hierarchically structured knowledge representation. In a later section we will show examples of this at higher grade levels. In the primary grades, students have not yet begun to take advantage of this capability but, as indicated, they are beginning to catch on to the basic idea of relational linking of notes. The remaining diagrams in Figure 4 illustrate the breadth of vocabulary use encouraged by their graphic displays and common word lists, and a different incubator diagram. All of the charts were drawn by children in Grade 1.

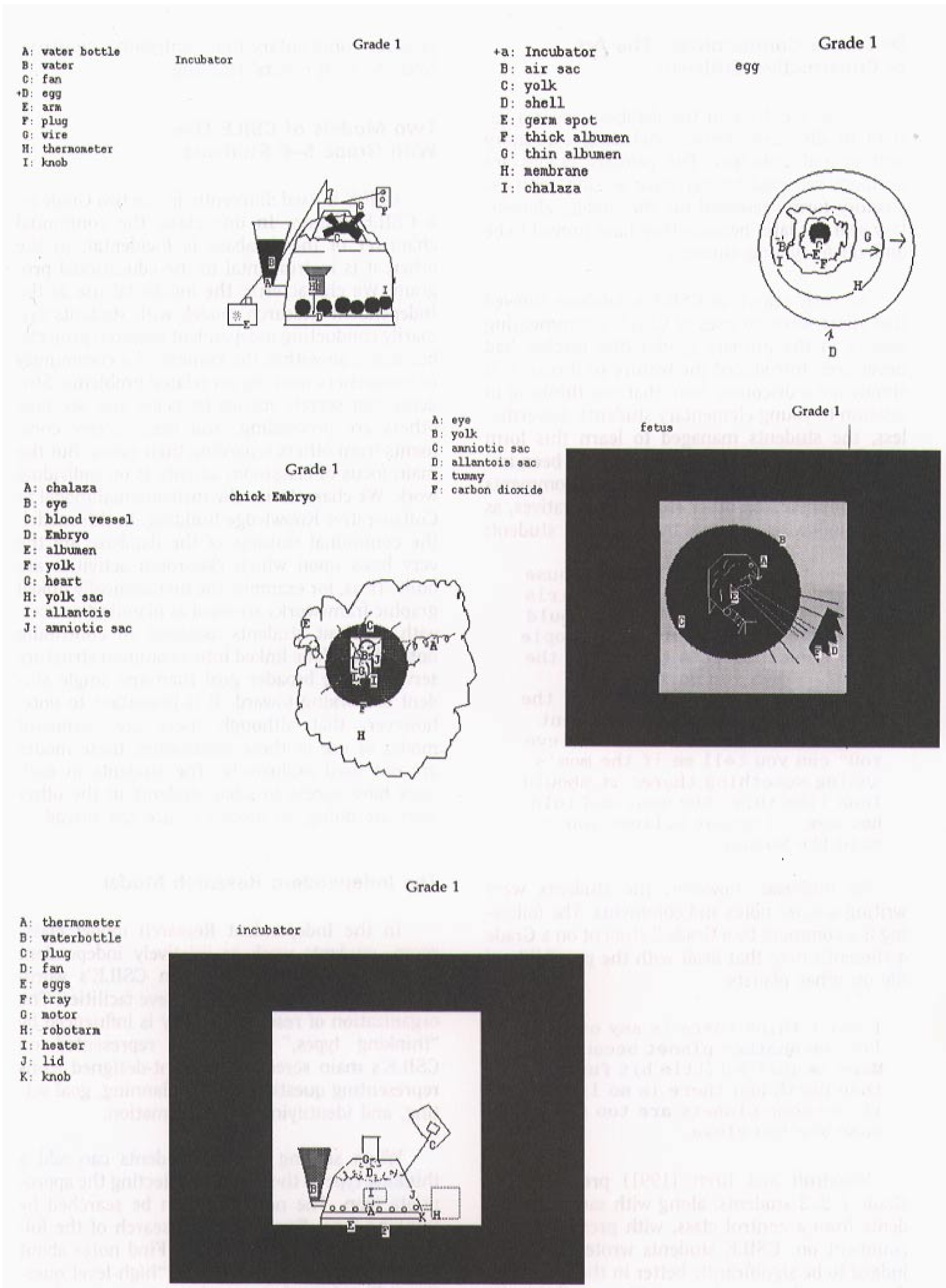


Figure 4. Diagrams of the egg-hatching process as illustrated by Grade 1 students

Discourse Communities: The Art of Constructive Criticism

Grade 1 entries in the database cover a variety of discourse forms, including expository writing and criticism. The primary grades are normally reserved for narrative writing, with expository forms reserved for the middle elementary years or later because they have proved to be difficult for young students.

An early search of CSILE's database showed that there were no uses of CSILE's commenting feature in the primary grades (the teacher had never even introduced the feature to them). It is simply not a discourse form that one thinks of in relation to young elementary students. Nevertheless, the students managed to learn this form with seeming ease and the results have been impressive. Not surprisingly, the earliest comments were comments on other students' narratives, as in the following example by a Grade 2 student:

```
I like this one. I like it because you put a
male in the story (girls don't often do that!!)
You should put THE END's on stories so people
will know that it's the end of the story. (When
you do, it might change the way people think of
the story.) When you print "she went and told
her mom. I do not believe you" can you tell me
if the mom's saying something there? It should
look like this: She went and told her mom. "I do
not believe you." said the Mother.
```

By mid-year, however, the students were writing science notes and comments. The following is a comment by a Grade 2 student on a Grade .4 student's note that dealt with the possibility of life on other planets:

```
I don't think there is any other life on another
planet because Mars is just a little bit further
than Earth and there is no life on it, so some
planets are too far and some are too close.
```

Woodruff and Brett (1991) presented the Grade 1-2-3 students, along with same-age students from a control class, with preset notes to comment on. CSILE students wrote comments judged to be significantly better in the sense that they provided more substance. These early results suggest that even quite young students are able to produce commentary that contributes constructively to each others' learning.

Two Models of CSILE Use With Grade 5-6 Students

CSILE is used differently in the two Grade 5-6 CSILE classes. In one class, the communal character of the database is incidental; in the other, it is instrumental to the educational program. We characterize the incidental use as the Independent Research model, with students primarily conducting independent research projects, but doing so within the context of a community of researchers working on related problems. Students can search entries by peers and see how others are proceeding, and they receive comments from others regarding their notes. But the main focus of classroom activity is on individual work. We characterize the instrumental model as Collaborative Knowledge Building. In this model, the communal features of the database are the very basis upon which classroom activities are built. Thus, for example, the hierarchically linked graphic frameworks are used as planning devices, with different students assigned to contribute notes that will be linked into a common structure serving some broader goal than any single student is working toward. It is important to note, however, that although there are dominant modes of use in these classrooms, these modes are not used exclusively. The students in each class have access to what students in the other class are doing, so models of use can spread.

The Independent Research Model

In the Independent Research model classroom, students work as relatively independent researchers, relying mainly on CSILE's wordprocessing and search-and-retrieve facilities. The organization of research activity is influenced by "thinking types," which are represented on CSILE's main screen by student-designed icons representing question asking, planning, goal setting, and identifying new information.

When signing a note, students can add a thinking type to their note by selecting the appropriate icon. The note can then be searched by thinking type. For example, a search of the following sort can be conducted: Find notes about explorers and of thinking type "high-level question." The following note by a Grade 6 student illustrates the thinking types.

```
Keyword: Alexander Graham Bell
Topic: Explorers
          What I Know
Some things I know about Alexander Graham
Bell is that he invented the telephone, a
Canadian
telephone company was named after him, and
that he was Canadian. He was also
acknowledged for his work greatly. He wasn't
I born in Canada.
         What I Wonder
1. Was Alex really smart? Or was he just good
   at communication?
2. Was anybody else thinking of how to make
   the telephone before Alexander discovered
   it?
3. How could Alex live with the fact that his
   father and grandfather had the same name as
   him?
```

```
4. Were there any other important inventions
   Alex created?
             I Plan
I plan to research and find out more about
Bell. I plan to know more about him. I also
plan to find out what was so great about
Alexander Graham Bell.
```

CSILE use in the Independent Research model classroom follows a pattern. For the most part, students enter a statement of what they now know, then elaborate what they wonder as a list of questions (frequently tagged with the thinking type "high-level question"). The challenge for the students is to then find answers to their questions. In order to cope with these demands, students seem to have invented a text-based question-asking strategy. The following notes suggest this strategy.

```
THE BLACK TAILED PRAIRIE DOG
          I know
The prairie dog is really a squirrel that
lives underground. It has a very short
tail.
          Questions
1. How old can he or she get?
2. Where did the name prairie dog come
   from?
3. How many babies does a prairie dog have
   a year?
4. Why does the prairie dog live under
   ground?
5. Do prairie dogs hibernate?
          Answers
1. (SORRY, I COULD NOT FIND IT OUT)
2. It comes from the prairie.
3. About the same amount as an ordinary
   dog.
4. So it can have shelter and protection.
5. Prairie dogs hibernate only in the
   colder parts.
```

Another child lists 20 Marco Polo questions tagged with the icon "high-level questions."

```
1. How long was Marco Polo in jail?
2. When did he go to China?
3. When did Marco Polo die?
4. When did Marco Polo leave his
   mother?...
20.Did Marco Polo have any medication?
```

Most of the questions that these two students asked are of a kind that we have labelled *text-based*. They appear to be either derived from a text or based on what the student confidently expects to find in an already-available text (Question 20 may be an exception). These are to be contrasted with *knowledge-based* questions, which arise from the child's own interests or efforts to make sense of the world. In research comparing these two kinds of student-generated questions (Scardamalia & Bereiter, 1991), we found that knowledge-based questions were generally rated higher in educational potential both by adult raters and by students. There is, however, substantial evidence that teaching students to ask text-based questions has a beneficial effect on learning (Rosenshine & Chapman, 1990; Wong, 1985).

The Individual Research model appears to be effective in getting students not only to ask but also to seek answers to text-based questions, and CSILE appears to have played a part. The teacher involved reported having made little use of student-generated questions prior to CSILE. Students in this class made extensive use of CSILE's facilities for creating, labelling, storing, and retrieving notes. However, what is most significant with respect to the topic of this article is that the communal character of the database is not crucial to this model. It could function if each student had his or her individual database, unconnected to the others. The question is whether it could function as well.

As we shall see, students in this classroom did interact via the database substantially less than the classroom we shall describe next. However, there were interactions, as the following example suggests. In the course of a biology unit, one student entered a note about sponges, which reported that they have three ways of reproducing. This curious revelation provoked a dozen notes and comments all related to the question of why sponges should have three ways of reproducing when the rest of us animals have to make do with only one. The advantages of back-up systems were duly noted, but this led one student to pose the more difficult question, `"Then why don I t other animals have three ways of reproducing instead of one?"` Pursuit of this question led not only to deeper consideration of differences between the life circumstances of sponges and other animals, but also to a closer analysis of what the several means of reproduction entailed. This in turn led to recognition that it is the structural simplicity of sponges, compared to higher animals, that enables them to reproduce by budding and regeneration. As it was put in one note, `"A stomach, lungs, a brain, and a heart, etc., could not grow on your finger if it was cut off."`

This example illustrates what can happen when a question with deep implications is seriously pursued by students interactively. A great deal of information normally organized around topics of reproduction, anatomy, growth, and the like, is brought together to solve the problem. Dry biological facts have been rendered more meaningful. Connections have been made between previously unrelated items of information. The world has, in a small degree, gained an increment of intelligibility in the process. That is the sort of knowledge-building activity that a communal database can support.

Although, as results to be reported later will show, students in the Individual Research model classroom made less use, in general, of the communal properties of the CSILE database, they made almost as many searches for notes by others as did students in the Collaborative Knowledge Building classroom. This suggests minimally that, even in a class where the focus is on individual work, students are curious about what others are doing. It is certainly the case that students in both classes show off the work of their peers when visitors are present. The models of effective work that they point to seem to set a standard and might lead to a general upgrading of their own work. Thus, even in the Independent Research model the communal database may play a significant role, giving students a sense that they are working within a community of researchers, with their work displayed within this communal context.

The Collaborative Knowledge Building Model

The model of CSILE use emerging in the other Grade 5-6 experimental class can be characterized by the following quotation from Dewey (1963):

> *The principle that development of experience comes about through interaction means that education is essentially a social process. This quality is realized in the degree in which individuals form a community group. It is absurd to exclude the teacher from membership in the group. As the most mature member of the group he has a peculiar responsibility for the conduct of the interactions and intercommunications which are the very life of the group as a community. (p. 59)*

Much greater use is made of the interactive capabilities of CSILE's communal database. The following anecdote from a parent of one of the students in this classroom suggests the more communal orientation. As the father reports, his son came home with the assignment of finding one important fact about germs. The father was taken aback, suggesting that his son would need to study more extensively if he were to learn about germs. But his son explained that everyone in the class was to find an important fact, so that by the next day, they would all have 32 facts to put together and then they would know quite a bit.

Distinctive communal uses of the database in this classroom include the following:

Group Planning. The use of CSILE charts and thinking-type plans as illustrated in Figure 5 is unique to this class. Students in this class have begun to work in groups and to assign different portions of the work to different team members. Their written and charted plans help them keep track of who is doing what.

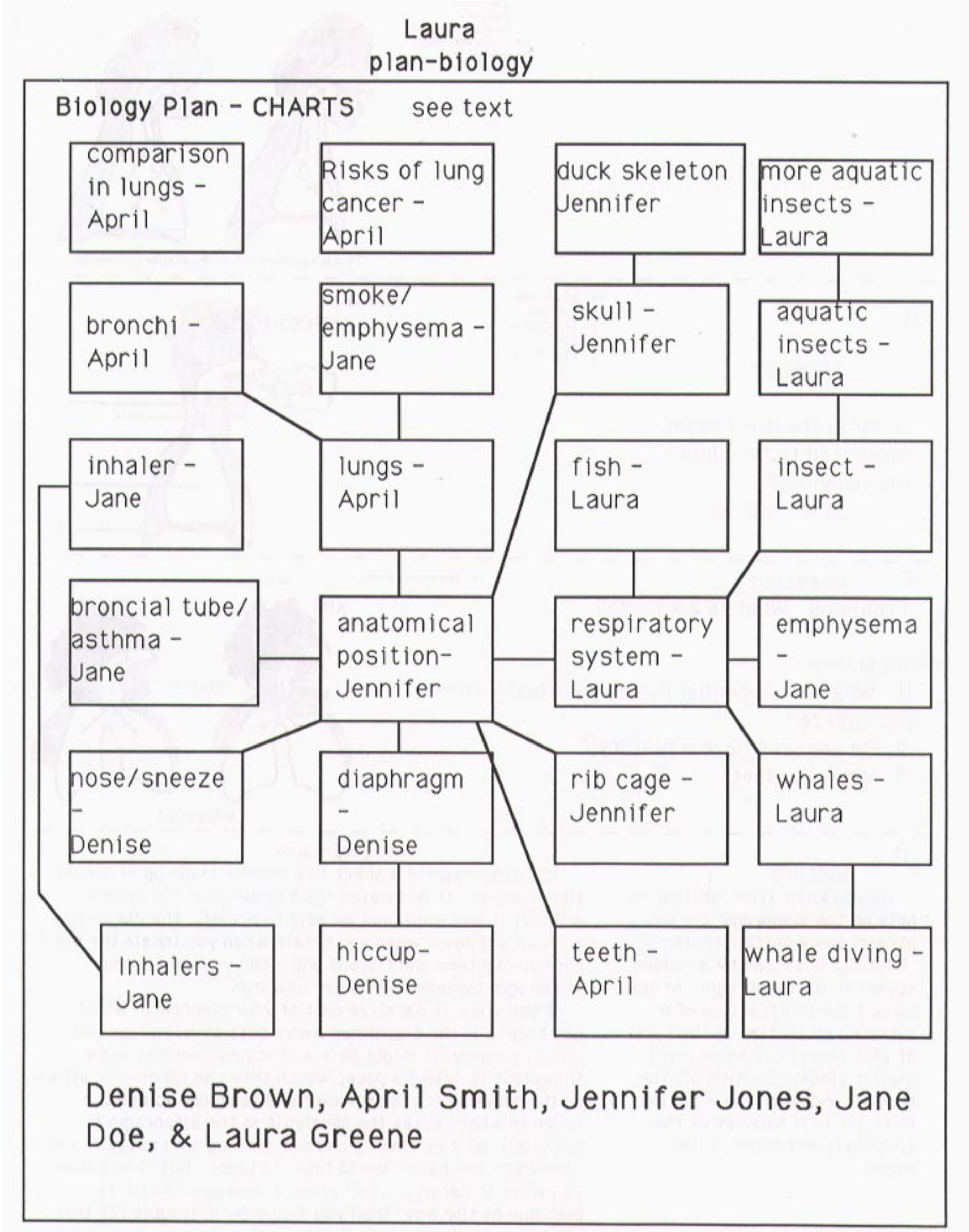
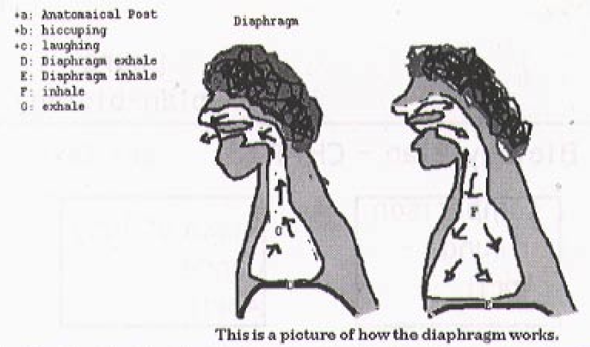


Figure 5. This figure illustrates spontaneous and early use of CSILE charts and thinking-type plans for a biology unit. Grade 5-6 students work in groups and assign different portions of the work to different team members.

Cooperative Pursuit of Explanations. The notes condensed into Figure 6 are a selection of notes generated by students all trying to work out an explanation of the diaphragm and its role. One graphic note (A) represents a student's attempt to show how the diaphragm works. Related graphic and text notes (B) by the same student are attempts to understand the role of the diaphragm in hiccupping. Another child is trying to figure out what happens inside your body when you sneeze (C). We also see elaborated notes (D), which present information discovered through research about how the diaphragm works and its relationship to hiccupping. Other notes in the database (not shown) deal with the relationship between the diaphragm and laughing. The result, in contrast to the independent note sets generated in the other classroom, is a set of notes by different authors that converge on a common problem, in this case, the problem of how the action of the diaphragm can produce such a variety of phenomena.

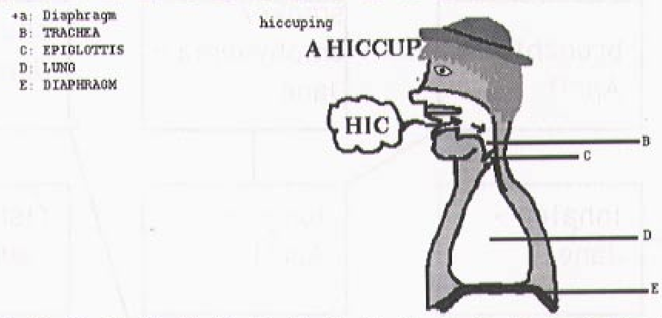
A



B

PROBLEM

How is the diaphragm connected to hiccuping and laughing?
Why do we hiccup?

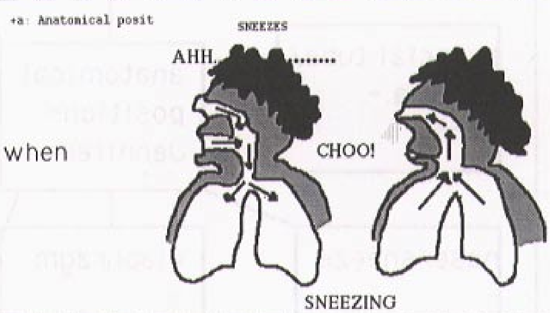


C Sneezing

Problems: What is a sneeze?

Questions:

1. What is happening inside your body when you sneeze?
2. Do sneezes have a history?
3. What is "snot"



D

HICCUPS

As you know from reading my note on the diaphragm the diaphragm has a certain rhythm.
A hiccup is caused by a sudden spasm of the diaphragm. At the same time in a fraction of a second a small flap at the back of your throat called your epiglottis closes blocking off the trachea and when the air tries to to get in it bounces of the epiglottis and makes a "HIC" sound.

The Diaphragm

The diaphragm is a sheet like muscle made up of string-like muscles. It is located right under your rib-cage and without it you would not be able to breath. The diaphragm goes up and down when you breath:when you inhale the diaphragm tightens and flatens and when you exhale the diaphragm loosens and curves upwards.

If you were to paralyze part of your diaphragm which can happen if the diaphragm nerve gets severed (usually during surgery) it might be o .k.. because there is something that is called a pacer which they can surgically attach to the nerve which is serving the diaphragm scince the nerve is what causes the paralysis in the diaphragm by obviously malfunctioning and not sending a message to the diaphragm the pacer would take its place. But if somehow you were to paralyze your whole diaphragm (which is possible by the way) then you would be in trouble for that is how some drugs cause death!

Figure 6. Grade 5-6 students attempting to explain the role of the diaphragm. Graphic note (A) represents an attempt to show how the diaphragm works. In related graphic and text note (B) the same student attempts to understand the role of the diaphragm in hiccupping. Another student tries to figure out what happens inside your body when you sneeze (C). Elaborated notes (D)

present information discovered through research about how the diaphragm works and its relationship to hiccupping.

Cooperative Commenting. Figure 7 shows schematically the connections among a set of notes and comments produced by six students working on a unit on human evolution. Most of the notes are produced by Ted, one of the lower achieving students in the class, who undertakes to study skulls. His first note indicates nine information sources he plans to use, with the nearby Royal Ontario Museum being first on the list. A comment from Rose suggests an exhibit at the museum that deals with skulls. Ted's next note lists names and ages of hominid skeletons he has noted. There follows a note with a hypothesis about evolution: "When a baby was born 4 million years ago and it had one change of its body closer to man like standing up straighter or having a different skull shape, that could be why our ancestors changed to be us." A comment by his friend, Wilf, points out the speculative nature of Ted's note, saying "The only real fact in it is that a baby was born 4 million years ago. That's not really much information." Ted subsequently produces a richly factual note and then summarizes his findings about skulls in a note that is commented on by Rog. Rog praises the note and asks six rather stimulating questions, including "Do you think that we might ever become apes again and why?" and "Why don't apes turn into humans anymore?" In the meantime, Wilf has produced a note of his own, summarizing his findings on the early history of tool use. Ted comments on this note, suggesting questions that would lead to a deeper analysis of the topic: "First you could add some information like about how the neanderthals could live through the ice ages and how could they make the fire ire in the cold?" Unconnected with Ted and his colleagues is a note by Amelia on Homo Erectus. Angie comments on this note, "I found the part about Homo Erectus's appearance very interesting. That's something that not many people know about. The part you wrote about fire was also quite interesting." Angie then mentions a clipping about Peking man that she thinks Amelia might find useful.

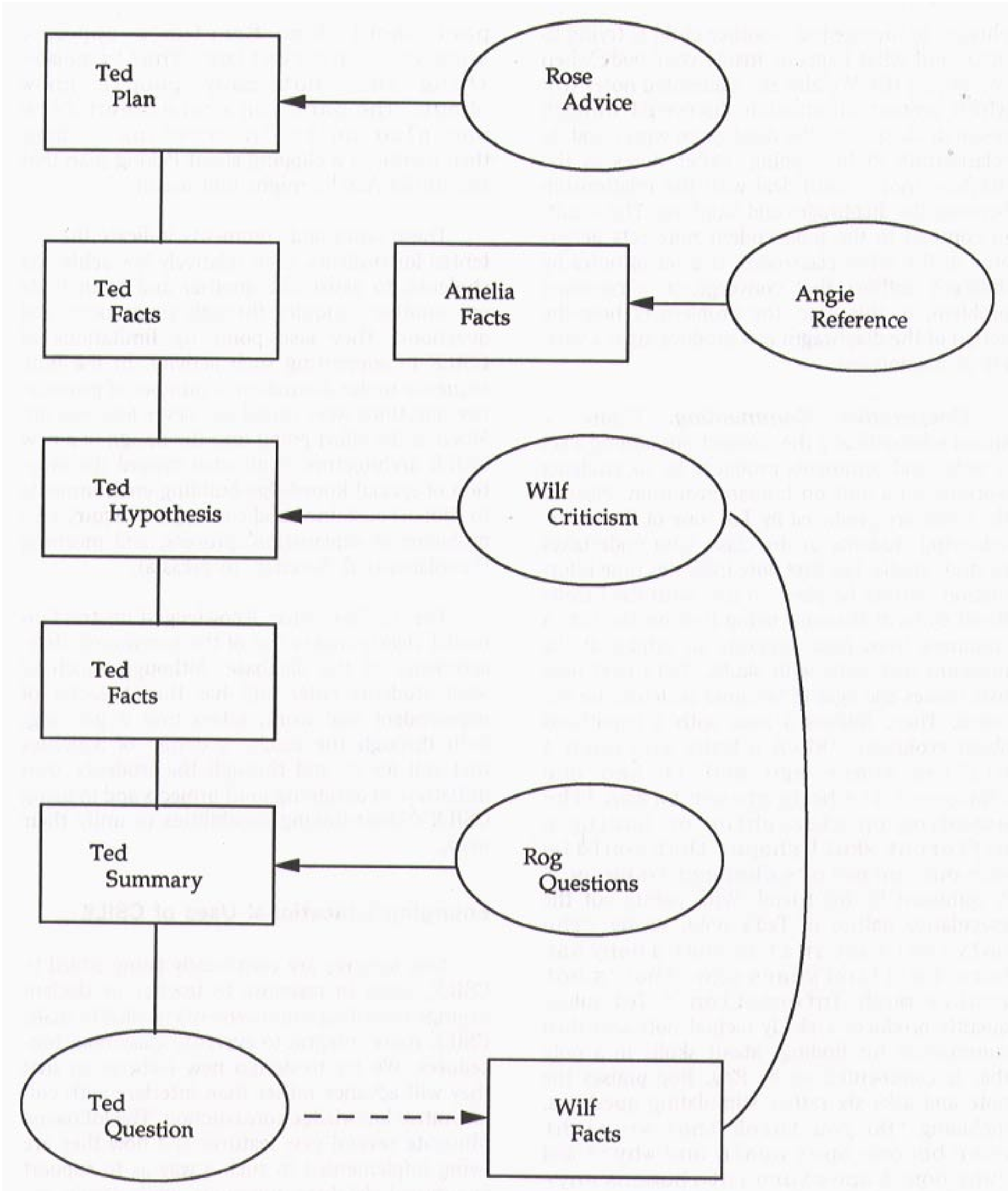


Figure 7. Cooperative commenting. Schematic representation of a set of related notes and comments. Rectangles represent notes; ovals represent comments. Time proceeds from top to bottom. See text for discussion of note content.

These notes and comments indicate the potential for students, even relatively low-achieving students, to assist one another and to upgrade one another's inquiry through suggestions and questions. They also point up limitations of CSILE in supporting such activity. In the note sequence under discussion, a number of provocative questions were raised but never followed up. Much of the effort going into the design of a new CSILE architecture is directed toward the creation of special knowledge-building environments to support sustained and convergent inquiry into problems of explanation, process, and meaning (Scardamalia & Bereiter, in press-a).

The Collaborative Knowledge-Construction model clearly makes use of the communal characteristics of the database. Although much of what students enter still has the character of independent seat work, interaction is growing, both through the teacher's design of activities that call for it, and through the students' own initiatives in designing joint projects and in using CSILE's chart-linking capabilities to unify their work.

Emerging Educational Uses of CSILE

New features are continually being added to CSILE, often in response to teacher or student urgings regarding improvements needed to make CSILE more integral to everyday classroom procedures. We try to design new features so that they will advance rather than interfere with collaborative knowledge construction. The following illustrate several new features and how they are being implemented in such a way as to support communal database functions while going beyond them in some way.

Linked Personal and Communal Dictionaries. A spelling checker has been added to CSILE, designed especially to support collaborative knowledge building. Instead of using a large preset dictionary, as conventional spelling checkers do, this one uses a dictionary created by the students. Students are encouraged to use the spelling checker when they have completed a note. If the spelling checker identifies a word that is not in the dictionary (which occurs frequently, of course) the student may confirm its spelling (consulting a conventional dictionary or asking someone) and add it to his or her personal dictionary. Tracking reports yield printouts of each student's personal dictionary, so that teacher and student can discuss entries. One teacher has actually given up all spelling activities that he used to conduct, and now simply holds a brief conference with each student concerning their personal dictionaries.

From time to time a program is run that collects all words that are correctly spelled in the students' dictionaries and adds them to the communal dictionary. Thus, students have pride and responsibility both in building their personal dictionaries and in contributing to the communal dictionary. The dictionary was initially seeded with 6,793 words that were already correctly spelled in the database. In the first 3 months of use, the number of words added from students' personal dictionaries was 1,383.

Portfolio Flag. As part of the evaluation of CSILE, students in both CSILE and non-CSILE classrooms keep portfolios of self-selected examples of their work. To facilitate self-selection of portfolio items from the database, we have installed a "portfolio" icon. Students are encouraged to use this icon to flag items that they think belong in their portfolios. Before a note can be flagged, the student is required to write an explanation for choosing it. Our intention is to create portfolios within CSILE so students can profile their work as well as contribute it to the communal database. Students have explained their choices for portfolio entries as follows: "I learned about using animals in research for medicine and because I learned that scientific things that are cruel to us, we test on animals," "...I am particularly proud of it. I think I did better in this because I am interested in the topic," and "This is my best writing and I am interested in baseball and because I like the way I put it together. And now that baseball is over I like this note also because it reminds me of baseball." Teachers seem pleased with student selections and commentary, especially given the fact that these comments were produced in the first week of use of this new feature. Portfolio procedures have been implemented in control and experimental classes. Lamon (1992) recently completed preliminary analyses which indicate that CSILE students write significantly better justifications for their selections and are significantly more constructive in their role as evaluators of the selections of other students. The creation of portfolios within CSILE provides a way of recognizing and enabling students to highlight individual achievements without detracting from an overall emphasis on collaborative knowledge building.

Summary of Educational Uses

We have seen how essentially the same system is employed at lower elementary grades in the cooperative development of print and graphical literacy and used in upper elementary grades to build domain knowledge, either through independent research or through more cooperative efforts. Although we will not elaborate here, the system has also been used in graduate school courses, where critical analysis of one another's contributions and deliberate effort to achieve coherence in the database are more evident. Unifying these diverse uses is the fact that the communal database objectifies knowledge in a way that conventional educational media do not, making it more possible to diffuse knowledge, revise and augment it, and bring it together into larger wholes.

The comparison of two models of use at the Grade 5-6 level demonstrates that a communal database does not impose a particular educational philosophy on teachers. It is possible to use it to support predominantly individualistic educational efforts or predominantly collective ones, or, what is most likely, a mixture of the two. Interestingly, the teacher who uses the Individual Research model relies on group processes to disseminate knowledge of CSILE itself; veterans teach beginners, a process facilitated by the mixed-grade composition of the class. The teacher who uses the Collaborative Knowledge Building model, on the other hand, is fairly direct in teaching students procedures of CSILE use. There is obvious room for flexibility, suiting the philosophies, styles, interests, and aptitudes of different teachers. Still, we believe the communal database introduces a bias toward collaborative knowledge building, as indicated by the instances of spontaneous interaction and cooperation that we have noted.

DATA ON EDUCATIONAL EFFECTS

The preceding section indicated promising kinds of activities and products arising from educational uses of a communal database. These are effects that visitors to CSILE classrooms can see immediately and that they generally applaud. But visitors also inevitably ask what evidence there is of educational effects, meaning test scores or other comparative indicators. In this section we present data of these kinds, but before doing so, we want to point out that the descriptive data already presented are also data on educational effects. The difference is that they indicate effects above the individual level: effects involving the knowledge-building activities of whole classes or groups within classes. Concerns with effects at the individual level are legitimate (especially on the part of parents), but such natural individualistic concerns should not blind us to the fact that the fortunes of societies often depend on advances made by groups or whole populations, and that education has a responsibility at this level too.

All of the data to be reported pertain to students in Grade 5-6, the data from lower grades being as yet too sparse. This section is divided into three parts. The first deals with educational outcome data, which show a number of advantages of CSILE classrooms over a control I classroom. They also show a number of differences between the two CSILE classrooms, however, the one identified previously with the Independent Research Model and the other with the Collaborative Knowledge-Building model. The second part presents tracking data describing quantifiable differences in the CSILE-related activities going on in these two classrooms. In the third part, regression analyses are reported which relate differences in classroom processes to differences in educational outcome.

Educational Outcomes of CSILE Use

1. Quantity of Writing. Grade 5-6 CSILE students produce about one word of text per minute of time spent signed on to CSILE. This is averaged over times that include reading other notes and producing graphic notes. Even at this rate, and averaging fewer than 30 min a day on CSILE, these students end up producing more original text than the average American high school student (Mullis, Owen, & Phillips, 1990). And this does not count other writing the students may do off CSILE. Thus, the relatively small amount of time students spend on CSILE appears to result in a comparatively large amount of writing.

2. Depth of Explanation. We have not evaluated students' writing stylistically, focusing instead on content, because this has been the focus of CSILE activities. A comparison was made of postinstruction writing samples from two science units, one from a CSILE classroom and the other from the control classroom. Writing samples (handwritten by both groups) were produced in response to the prompt: "What I have learned from doing this unit." Responses were scored on a wholistic scale of Depth of Explanation (see Table 1). The CSILE students scored significantly higher than the control students *(M = 2.89 vs. M* = 1.20; $t(35) = 7.09$, $p < .001$), indicating that CSILE students were attempting to construct explanations or at least coherent accounts, rather than simply listing discrete facts that are only loosely connected.

Table 1. Depth of Explanation Scale[a]

Levels of Inquiry Used to Rate Student Texts to Assess the Degree to Which Students Attempt "Systems" -Level Explanations Instead of Listing Facts
1. Isolated facts The text primarily consists of discrete bits of information, listed but not necessarily related or integrated. *(e.g., a list of facts about plant reproduction)*
2. Local integration of facts The text contains a local description of some aspect of the topic area. Related facts are grouped together and describe some aspect of the topic. *(e.g., a description of the different parts of the plant)*
3. Facts are grouped towards the construction of an explanation The text primarily consists of facts grouped together such that they begin to *sketch or suggest* an explanation for why something may occur within the topic area. *(e.g., a description of two different types of plant reproduction: asexual and sexual reproduction)*
4. Networks of related facts that indicate an explanation The text indicates a more elaborate attempt to explain the topic area as a functional system. *(e.g., an explanation of the different ways in which plants reproduce: What are the different ways and how do they work?)*
5. Elaborate description of the topic area as a system In this case, the text provides an explanatory account of how the system works. Furthermore, the text also demonstrates that the student has extended or applied his or her knowledge of the process to a novel situation. (*e.g., an explanation of the plant reproduction process and an application of this knowledge by attempting to explain how plants might survive on the planet Mars)*

[a]Burtis, Rukavina, and Scardamalia (1988).

We collected writing samples again this year, using the same basic design. A new depth-of explanation scale titled, Constructive Activity, sought to capture more of the kinds of constructive activities involved in producing essays with explanatory power (see Table 2). Two raters, blind to condition, rated each essay on each of the five indices, then the five scores were added to create a composite score (interrater reliability = .82). Analysis of variance (ANOVA) on the composite scores showed a significant effect in favor of the CSILE classes, $F(2, 76) = 39.25$, $p < .001$. Unfortunately, one of the experimental teachers forgot to present the writing assignment at its appropriate time, with the result that six students had already left for summer vacation and the remainder completed the task under pressured conditions. Whether this is the reason or not we cannot be sure, but post hoc (Sheffé) tests showed only the other experimental class to be significantly different from the control.

Table 2. Constructive Activity Scale

1	2	3	4
1. No indication that the student is interested in the topic or attaches personal importance to any of the information.			Indications of ownership and involvement in the material.
2. Superficial treatment of information.			In depth analysis of information.
3. Text is mainly a list of facts.			Text is coherent.
4. Reporting of information.			Explanations of information.
5. Passive reception of information.			Evidence of problem solving or creative effort toward understanding.

3. Knowledge Quality. The preceding analysis shows differences in what students were trying to do, with CSILE students trying to achieve greater coherence and deeper levels of explanation with respect to what they had learned. Whether what they claimed to have learned was correct or misconceived, central or peripheral to the topic, are separate matters, which were rated by a separate composite of 10 scales. The 10 scales are titled Knowledge Quality and are shown in Table 3. The same "What I learned" texts as discussed in the preceding paragraph were independently rated on these Knowledge Quality scales (reliability of composite scores, using two raters = .86). ANOVA results were similar to those obtained with the Depth of Explanation scales: A significant difference favoring CSILE classes over the control class, $F(2, 77) = 46.74$, $p < .001$, but post hoc tests showed only one of the CSILE classes to be significantly superior.

Table 3. Knowledge Quality Scale

1	2	3	4
1. Text contains significant misconceptions.			Text contains mostly accurate content.
2. Text focusses on very limited part.			Text shows knowledge of area as a whole.
3. Text consists of facts.			Text deals with ideas as principles.
4. Ideas are unconnected or wrongly connected.			Ideas are connected correctly.
5. Text deals mostly with trivial facts.			Text focusses on facts relevant to understanding.
6. Text shows only common sense understanding of material.			Text shows understanding that goes beyond common sense understanding of material.
7. Text treats all information as authoritative.			Text shows awareness of uncertainties, controversy.
8. Text consists of personal views mistaken for or confused with established knowledge.			Text contains personal views clearly distinguished from established knowledge.
9. No demonstrated awareness of how knowledge in the domain is obtained.			Explicit reference to how knowledge in the domain is obtained.
10. Minimal or no apparent understanding of topic.			Substantial overall advance in understanding of topic.

4. Question Asking. Within-CSILE-class results suggest that the question-asking abilities of students in both experimental classes are remarkable, at least by the standards we used to judge their text-based and knowledge-based question-asking abilities (see above). In order to provide experimental-control data with respect to question-asking abilities we asked students in our three Grade 5-6 classes to write questions on a topic they were about to study. Before study began they were asked to generate questions about "What I wonder about x" (the topic to be studied, which was selected by the teacher). We rated their questions on a scale ranging from asking about isolated facts (at the low end) to asking for explanations (at the high end). Results on this measure were affected by the same error in data collection that affected the essay-writing task: namely, the assignment was given under pressured end-of term conditions in one experimental class. That class looked much like the control class. The other experimental class, the Collaborative Knowledge-Building class, showed significantly higher scores, $F(2, 76) = 4.51$, $p < .01$.

5. Standardized Achievement Test Scores. All students in our Grade *5-6* experimental and control classes completed five subtests of the Canadian Test of Basic Skills, a battery similar to the California Test of Basic Skills. The subtests were administered as a pretest in October and again (with alternate forms) as a posttest in June. As expected, there were no significant differences on any pretests, nor on the two mathematics posttests. (No CSILE-related work in mathematics had been done at this time.) When pre- and postdifference scores on the language subtests were combined and averaged (reading comprehension, spelling, and vocabulary), we found significant experimental/control differences in favor of the CSILE classes, $F(2, 78) = 7.17$, $p < .01$. Post hoc (Sheffé) analyses revealed that the differences between each CSILE class and the control class were significant (see Figure 8).

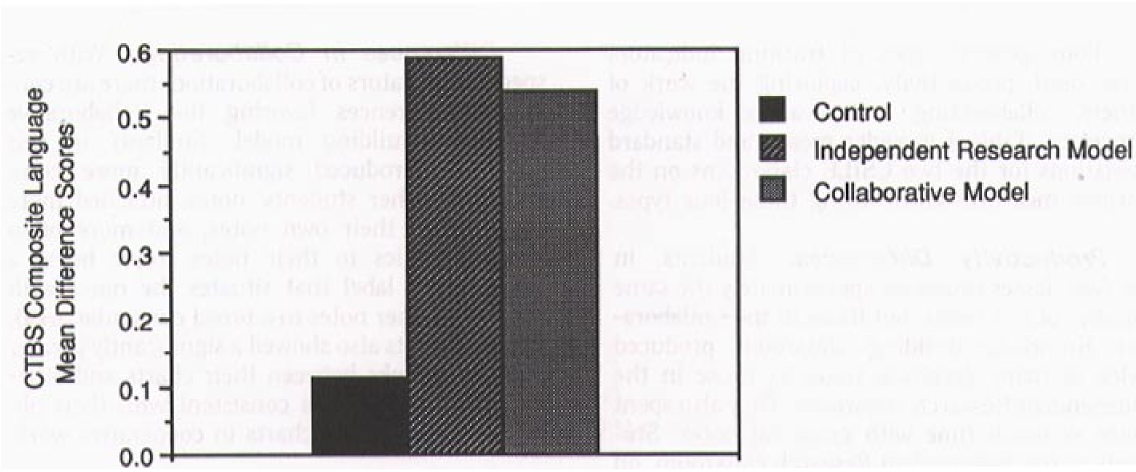


Figure 8. Pre- and postdifference scores on the language subtests (reading comprehension, spelling, and vocabulary) of the Canadian Test of Basic Skills

Of the three language subtests, vocabulary was the only one that showed significant group differences on its own. Sheffé tests showed that both CSILE classes were superior in gains to the control class, and also that the two CSILE classes differed significantly from each other. The CSILE class showing the greater gains was the one identified with the Independent Research model.

In order to investigate how students of different achievement levels were faring in the CSILE environment, we divided each class into below, at, and above grade-level groups on the basis of their incoming language composite CTBS grade equivalent scores. Mean gain scores for these subgroups are shown in Figure *9*. There was a significant difference among achievement levels, $F(2, 75) = 9.86$, $p < .001$, reflecting a tendency for students at or below grade level to gain more than those above grade level at pretest. Although Figure *9* suggests that this effect may have been stronger in the experimental than in the control classes, the interaction between class and achievement level was not significant, $F(4, 75) = 1.60$, $p = .183$. At any rate, this result discourages any suggestion that CSILE is only effective with high-achieving students.

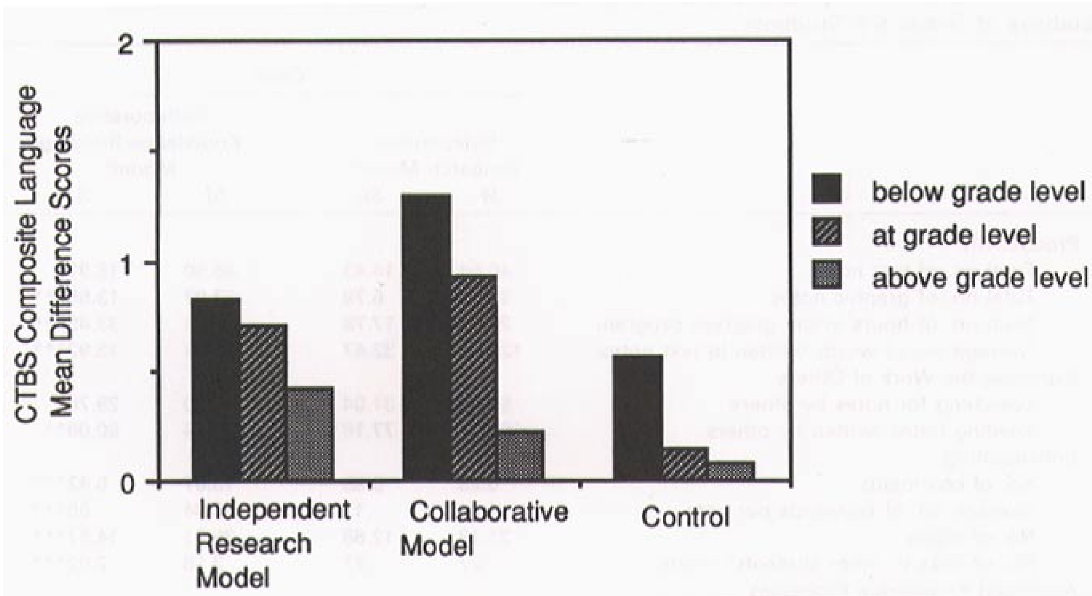


Figure 9. Mean gain scores for students below, at, and above grade level on the basis of their incoming language composite score

Quantitative Differences in CSILE Activities

Tracking facilities that we have designed and implemented now permit us to compile information regarding student use of CSILE's various functions. Comparing the tracking profiles of the two Grade 5-6 CSILE classrooms was of interest both because of the different models of use represented-namely, the Independent Research model and the Collaborative Knowledge-Building model-and because of the educational outcome differences noted in the previous section. These generally favored the Collaborative Knowledge Building model except in the interesting case of vocabulary development. We wanted to see if there were identifiable differences in CSILE use that could be related to differences in structure and outcome.

Four general types of tracking indicators were used: productivity, exploring the work of others, collaborating, and advanced knowledge processes. Table 4 provides means and standard deviations for the two CSILE classrooms on the various measures constituting these four types.

Table 4. Means and Standard Deviations of CSILE Tracking Data from 1989/1990 CSILE Database of Grade 5-6 Students

	Class			
	Independent Research Model[a]		Collaborative Knowledge-Building Model[b]	
	M	*SD*	*M*	*SD*
Productivity				
Total no. of text notes	40.64	14.43	46.50	18.91*
Total no. of graphic notes	13.59	6.79	27.07	13.55***
Total no. of hours in the graphics program	20.29	17.78	39.31	33.49***
Average no. of words written in text notes	120.33	32.47	86.31	18.92***
Exploring the Work of Others				
Searching for notes by others	55.05	31.04	66.50	29.70*
Reading notes written by others	108.18	77.16	151.64	80.08**
Collaborating				
No. of comments	5.23	3.35	10.07	5.42***
Average no. of keywords per note	1.14	.17	2.34	.56***
No. of topics	21.18	12.68	39.21	14.87***
No. of links to other students' charts	.27	.77	2.18	2.02***
Advanced Knowledge Processes				
Thinking Types	7.05	5.46	23.50	13.49***

[a]n = 22. [b]n= 28.
Significance level for difference between models: *n.s. **p = .06. ***p < .01.

Productivity Differences. Students in the two classes produced approximately the same number of text notes, but those in the Collaborative Knowledge-Building classroom produced twice as many graphical notes as those in the Independent Research classroom. They also spent twice as much time with graphical notes. Students in the Independent Research classroom, on the other hand, showed a significantly higher average number of words written in text notes. The greater use of graphics by students in the Collaborative Knowledge-Building classroom is consistent with their observed use of linked graphics as a means of cooperative work.

Differences in Exploring the Work of Others. Although the two classes did not differ in the number of searches they performed, there was a trend for students in the Collaborative Knowledge-Building classroom to read more notes written by others, as indicated by the number of notes by others that were kept in the read window for a minimum of 2 seconds.

Differences in Collaborating. With respect to indicators of collaboration, there are consistent differences favoring the Collaborative Knowledge-Building model. Students in this classroom produced significantly more comments on other students' notes, attached more keywords to their own notes, and more often assigned topics to their notes (topic being a higher-order label that situates the notes with respect to other notes in a broad curricular area). These students also showed a significantly greater number of links between their charts and other students' charts, as is consistent with their observed use of linked charts in cooperative work.

Differences in Advanced Knowledge Processes. The most accessible indicator in this category is the total number of times that a student assigns a thinking-type icon to a note. The assignment of thinking types is not mandatory; thus, assignment suggests that the student is knowingly engaged in formulating questions, plans, problems, or new knowledge and is taking the time necessary to indicate this. Significant differences favored the Collaborative Knowledge Building model.

In summary, the tracking data are consistent with more qualitative observations of differences between the two classrooms. Students in the Collaborative Knowledge-Building classroom showed more evidence of exploring each other's work and of collaborating. They spent more time with graphics, as is consistent with their use of this as a cooperative medium. Students in the Independent Research classroom produced longer text notes, as is consistent with the systematic approach in this classroom that involved using CSILE notes to formulate what they knew about a topic, their questions for research, and their answers. It is interesting that, despite this emphasis on thinking types, it was students in the Collaborative Knowledge-Building classroom who made more use of thinking-type icons to label their notes.

Relations Between Tracking Data and Educational Outcomes

Because the two classrooms differed significantly on many variables of CSILE use and also showed some significant differences in educational outcome, we naturally want to know whether there is a relationship between how students use CSILE and educational outcomes. To investigate this question, we used multiple regression analyses. The independent variables or predictors used in the analyses were as follows:

1. *Prior achievement:* a composite formed from average grade-level scores on the five Canadian Test of Basic Skills pretests relative to grade level. This variable was introduced first, on the premise that overall achievement level would account for significant variance in any learning outcome, and that this variance should be controlled before looking for additional predictive variables.

2. *Productivity:* a composite of total number of text notes and total number of graphics notes.

3. *Exploring:* a composite of number of searches of the database and number of notes read (as explained in the preceding part).

4. *Collaborating:* a composite of number of comments, number of keywords, assigned per note, number of notes assigned to topics, and the number of links to other students' charts.

5. *Thinking-type use:* the number of notes tagged with thinking-type icons, taken as an indicator of advanced knowledge processes.

The composites making up Variables 1-4 were formed by standardizing scores for each variable and averaging the standardized scores. The dependent variables or criteria being predicted were the Constructive Activity composite score (based on factors set out in Table *2)* and the Knowledge Quality composite score (based on factors set out in Table *3).*

The multiple regression analyses were run by entering variables one at a time in the order indicated and testing at each step whether the variable contributed significant additional variance to the prediction. When analyses were run over the two Grade *5-6* classes combined, no predictors were significant except for Achievement pretest, and it was only significant in predicting Knowledge Quality, not Constructive Activity. The analyses were then run separately for each class.

Again, no significant prediction of Constructive Activity was obtained. In predicting Knowledge Quality, however, interesting differences appeared, as shown in Table 5. In the Independent Research classroom the two significant predictors of Knowledge Quality are productivity and thinking-type use. In the Collaborative Knowledge Building classroom the significant predictors are exploring and collaborating, the two measures of communal activity. (Prior achievement falls just short of significance as a predictor in both classes.) Thus, the results are amazingly consistent with the observed nature of CSILE use in the two classes. In the Independent Research classroom, where students are generally working on their own, overall productivity, as indicated by number of notes produced, predicts learning. Use of thinking-type markers is also a predictor, reflecting the curricular emphasis on use of thinking types to guide independent inquiry. In the Collaborative Knowledge-Building classroom, learning is related to the extent of the student's involvement in knowledge-sharing and collaborative activities.

As is always the case with correlational results, causality cannot be inferred. It may be that students who are good learners are also ones who do the kinds of things expected of them in a classroom, but that the two are not causally related. The congruence between models of CSILE use and predictors of learning is nevertheless notable, given that they are experimentally quite independent, and makes it plausible that there could be a causal connection. If there is, it is not a simplistic causal connection that shows one kind of CSILE use to be effective and another not. Instead, it would indicate that there are alternative routes to learning which can be effectively supported by different models of CSILE use.

Table 5. Regression of CSILE and Other Predictors on Knowledge Quality and Constructive

	Independent Research Model			Collaborative Knowledge-Building Model		
Variable Entered	R^2	Increase	p	R^2	Increase	p
Regression of 7 Predictors on Knowledge Quality						
Age, CTBS-M, CTBS-V	.14	.14	n.s.	.25	.25	.07
CSILE Productivity	.31	.17	.05	.25	.00	n.s.
CSILE Communal 1	.35	.04	n.s.	.38	.13	.04
CSILE Communal 2	.45	.10	n.s.	.51	.13	.03
CSILE Advanced Processes	.60	.15	.04	.52	.01	n.s.
Overall significance of 7 predictors			.04			.02
Regression of 7 Predictors on Constructive Activity						
Age, CTBS-M, CTBS-V	.15	.15	n.s.	.13	.13	n.s.
CSILE Productivity	.15	.00	n.s.	.13	.00	n.s.
CSILE Communal 1	.15	.00	n.s.	.22	.09	n.s.
CSILE Communal 2	.28	.13	n.s.	.22	.00	n.s.
CSILE Advanced Processes	.49	.21	.03	.22	.00	n.s.
Overall significance of 7 predictors			n.s.			n.s.

DISCUSSION

Having presented a variety of results and observations, we now return to the central question addressed in this article: the educational usefulness of a communal database. Three points need to be reiterated as framing for this discussion:

1. We are considering a student-generated communal database as the centerpiece of the elementary school curriculum, around which a large part of the academic program is organized. We are not considering a communal database as a special purpose tool. It might have such uses, but the present findings do not bear on them.

2. Placing a communal database at the center of the school curriculum could well represent a radical, not just an incremental change in curriculum design. There are varieties of school-based media for cooperative work, including bulletin boards, where student productions are posted, and cooperative projects where a number of students contribute. But none of these could support the range of knowledge-aggregating and collaborative interactions described in preceding sections.

3. It is not sufficient to think of educational uses in terms of the transfer of existing educational functions to a system like CSILE. The potential educational uses are to be discovered and invented. The CSILE teachers report that what they have done to date represents only a beginning. As they gain further experience and interact with other teachers using the system, they become more inventive and find unanticipated uses of system capabilities.

Learning as Public Knowledge Construction

The shift implied by making a communal database the center of the curriculum may be interpreted as a shift in focus. In conventional schooling, the focus is on a body of knowledge that exists "out there" (typically in books), and that is to be taken in or reconstructed internally by the student. With a communal database, the focus is on a body of knowledge being constructed "in here" (that is, in the classroom's database), with information from "out there" being used in the construction. Thus, the shift is an epistemological and not merely a methodological one. Notice that the distinction being made is not the same as the more familiar one between education viewed as pouring knowledge into students' heads, and education viewed as helping students construct their own knowledge. On both sides of the latter distinction, the focus is on knowledge as held by individual students, whereas with the radical shift we are talking about, the focus is on public knowledge jointly constructed by students. What gets represented and retained in the individual mind is, of course, important, but it is not what the curriculum is focused on.

This shift in focus from individual cognition to public knowledge construction is not unique to a CSILE-like system. It is shown dramatically in a report by Brown and Campione (1990) on a "jigsaw" classroom organization, in which different students study different aspects of a topic and then come together to produce a coherent paper on the topic. The main indicators of achievement used by Brown and Campione in this report are advances in the content and organization of these jointly produced papers. Again, individual learning is considered important, but the actual focus of instructional activities and of evaluation is on the publicly constructed knowledge. Of course, this is also the focus of activities and of evaluation in the learned disciplines, which have served as a model for both CSILE design and Brown and Campione's instructional design.

This is not the place to address all the epistemological and pedagogical issues that this shift in focus stirs up. Some of these are addressed in Scardamalia and Bereiter (in press-b) and Bereiter (in press). A more immediate and empirical question is whether this claimed shift in focus is in any way reflected in the behavior of teachers or students. What we must look for, then, is evidence of a shift from focusing on individual performance, on the mastery of a set body of subject matter, and on activities themselves, to focusing on the emerging body of knowledge represented in the database.

The main evidence of such a shift that is brought out in the findings here is the variety of convergent evidence showing two different models of CSILE use in Grade 5-6 classrooms, what we have termed the Independent Research and the Collaborative Knowledge-Building models. Neither of these are traditional models of didactic instruction; both turn a great deal of initiative over to the students. Yet, the Independent Research model retains much of the traditional focus on individual performance, whereas the Collaborative Knowledge-Building model shifts away from this toward a focus on the construction of shared knowledge.

Data presented in this article show that the distinction between these two models is not just nominal, that it has empirical consequences. Tracking data show different distributions of CSILE activity in the two classes that are consistent with the models. Outcome data also show differences in line with what is emphasized in the two models: students in the Independent Research model excelling in vocabulary development, students in the Collaborative Knowledge Building model tending to excel in knowledge quality and constructive activity. Regression analyses show relations between process and outcome that are consistent with the models: Students who do more of what the prevalent model in their classroom intends for them to do obtain higher scores on knowledge quality.

Although we would like to think of these phenomena as straws in the wind, indicating a general drift toward public knowledge construction, we must also reckon with the fact that they are relatively rare occurrences that are a long way from typifying CSILE use. Nevertheless, we would argue that these occurrences are significant. Although school requirements, parental expectations, and the like, ensure that much of classroom life will fit the conventional mold, there is evidence from the collaborative model that a classroom can function well and achieve superior results educationally with a greatly diminished emphasis on individual achievement and an explicit focus on public knowledge construction. Students, representing quite a heterogeneous mix, adapt to it readily and some of them take off dramatically, beginning to function much like research teams or scholarly groups.

Knowledge Construction and the Conventional Goals of Schooling

A recent article in *Science* (Holden, 1989) assembled expert opinions opposed to "constructionism" as it is currently being advanced by educational theorists. For instance, Andrew Molnar, director of the National Science Foundation's program for Advanced Applications of Technology, was quoted as saying "the constructionist environment is very inefficient and in many cases nonproductive" (Holden, 1989, p. 909). The kinds of educational uses of a communal database that we have been discussing clearly fall within the constructionist category, and indeed might be considered extreme even there. The main complaints against construction ism, as applied to education, are that (1) it ignores the more mundane but essential goals of schooling, learning to read, spell, calculate, and so on, and (2) it presupposes a kind of intrinsic motivation not actually present in many schoolchildren.

Data from standardized testing provide no basis for the first complaint. As reported, CSILE classes did as well on all achievement measures as the control class and in the language area -comprising reading, vocabulary, and spelling-showed superior gains. As to the second complaint, we cannot give a fully satisfactory response on the basis of experience to date. Students using CSILE have included visible minorities, recent immigrants with limited English, children with learning disabilities, and children from single-parent, low-income homes. But CSILE has not been tried in classes where these kinds of students constitute the overwhelming majority. Because public knowledge construction depends on students working together as a community, the overall classroom climate or culture is important. We would have to acknowledge that the classroom climates that CSILE has been brought into have been very favorable from the beginning. We do not yet know how CSILE may fare in less favorable surroundings, although CSILE lends itself to enough variations in teaching and management that we are confident ways can be found to make it work. What we can say on the basis of experience, however, is that when a supportive classroom atmosphere exists, children of all kinds are able to join profitably in work with a communal database. Individual differences in motivation and ability are still apparent, but we see no reason to believe that the kind of intrinsic motivation required for productive participation in a CSILE environment is limited to a student elite. This conclusion is supported by the finding that achievement test gains tend to favor the students scoring at or below grade level more than those scoring above grade level.

Nontraditional Educational Outcomes

Everyone recognizes the limitations of standardized achievement tests, but suggestions as to what is lacking run toward "higher-order skills" or even more vaguely defined educational outcomes. The findings reported here point to several more definite kinds of outcomes that appear to be valuable and, at least potentially, measurable.

1. Graphical Literacy. Gains by CSILE students in ability to produce and interpret graphical communications have not been evaluated systematically, and to do so will be a challenge. But samples of work, such as provided in this article, are striking enough to make a case for graphical literacy as an important educational outcome that needs to be assessed, and this is likely to be fostered by work in a multimedia communal database environment.

2. Knowledge Quality. Traditional measures assess knowledge by counting discrete items of knowledge that students demonstrate. Quality and coherence are not assessed. Our results show that they can at least be reliably assessed by global ratings and that students in CSILE classes show significant advantages in knowledge quality over comparable students in a conventional classroom.

3. Level of Constructive Activity. There is much talk in education circles about assessing "process" rather than "product." This kind of talk is alarming insofar as it suggests that in future it may not be sufficient for students to produce good essays or demonstrate sound knowledge, they will have to show that they used the correct strategies in achieving these ends. The rating of constructive activity used in the research here is based on earlier research (Chan, Burtis, Scardamalia & Bereiter, 1992) and does not aim to assess the use of particular processes or strategies. Rather, it aims to assess the level of activity of any kind that the student appears to be putting into constructing new knowledge, as indicated by thinking-aloud protocols collected in process. Although this method has obvious limitations, it is reliable and is related in appropriate ways to more substantive educational outcomes. It is also a measure that shows significant advantages for students working with a communal database.

Independent Versus Collaborative Models of Database Use

Much of the discussion in this article has dealt with the two models of CSILE use found in Grade 5-6 classrooms. It should be obvious that our bias is toward the Collaborative Knowledge Building model, and results on the whole point to its viability and educational effectiveness. Results also suggest that the Independent Research model is a viable one, with educational advantages over a conventional classroom. Putting the Grade 5-6 results together with the observations on younger children's uses of CSILE, the more compelling conclusion to be drawn is that exciting things can happen when the school curriculum starts to be shaped around children's contributions to a communal database. There is a great deal of room for innovative experimentation, both at the level of system design and at the level of models for use.

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