Instructional Models in Computer-Based Learning Environments

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Two models of classroom learning using a communal database

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Abstract: Teachers using CSILE, a networked hypermedia system with a student-constructed communal database, evolved two distinct models of use, an Independent Research model and a Collaborative Knowledge-Building model. The Collaborative model showed superior gains in knowledge quality, the Independent model, superior gains in vocabulary. Regression analyses showed different patterns of relationship between process variables and outcomes, consistent with the hypothesized models. Although both models appear viable, the Knowledge-Building model makes fuller uses of the potential of new knowledge media.

Keywords: collaborative learning, computer-assisted instruction, communal database, CSILE, hypermedia, implemented models, interactive learning environments, instructional strategies, intentional learning, knowledge-building model, learning, restructuring

Introduction

Ever since the earliest days of educational computing, there have been suggestions that computers might lead to a fundamentally different kind of education rather than incremental improvements to education as we already know it [2]. Probably everyone would agree that the changes, if any, brought about by the introduction of microcomputers into schools have been superficial [1, 3]. There is skepticism, moreover, about even the more radical of experimental uses of computers in education. A variety of experimental work (including that of the present authors) was reported in a symposium at the 1990 meeting of the American Educational Research Association, titled "Technology and Restructuring: Creating a Context for Learning and Evaluation." The discussant, educational historian Larry Cuban, dismissed these efforts as merely another attempt to revive Progressive Education.

One reason that claims about fundamental change may fail to get across is that experimental innovations tend to be contrasted with a stereotype of conventional didactic practice that is already rejected by the great majority of educators. It is therefore easy to assimilate the proposed new vision to the familiar "new" vision represented by Progressive Education and its many descendants. This is particularly true of those innovations that involve a good deal of student autonomy and interaction. They break the pattern of the teacher standing in front of the room and lecturing or drilling the students, but they do so in ways that readily evoke familiar notions of child-centeredness, inquiry learning, open education, and the like.

It is impossible, in short, to get much conceptual mileage out of contrasts between an idealized high-tech learner-centered classroom and a caricatured no-tech teacher-centered classroom. More refined contrasts are necessary, not only to communicate what is distinctive about new approaches but also to clarify goals and identify problems. In this chapter we present a naturally occurring contrast between the ways two highly competent teachers use the same computer-based learning environment. Besides describing the two approaches, we will present process data showing differences in how students in the two conditions used the technology, differences in learning outcomes, and -perhaps most interesting - differences in the relationships between process variables and learning outcomes.

Background

The two grade 5-6 teachers whose classes provided the data for this comparison were both in their fourth year of using CSILE (Computer-Supported Intentional Learning Environments) in their elementary school classrooms. We will not describe CSILE in detail here, since that has been done elsewhere [7, 9]. Briefly, CSILE is a hypermedia system built around a student-generated database. The work students do in various academic subjects is entered as text or graphical notes into a common database, where all users may have access to it and comment on it. By the time of the present study, both teachers were using CSILE extensively in all parts of the curriculum except mathematics. (Mathematics applications are currently being tested.) The CSILE installation in use during the period of this study consisted of 8 Macintosh IIx microcomputers in each classroom, all 16 computers being linked to a 17th Macintosh IIx, which acted as a file server. In principle, students could have 90 minutes each per day on CSILE, although the intrusion of other activities resulted in actual use being about 30 minutes per day. A fuller picture of how CSILE functions will emerge from later description of the two approaches to using it.

The kind of fundamental change in education that we have taken as a long-term goal of CSILE is the restructuring of classrooms into knowledge-building communities [8]. In ordinary classrooms, whether they follow a direct instruction or an open education model, the focus is on tasks and activities. With CSILE, we hope to move knowledge to the center of the stage rather than leaving it in the background. The student-generated communal database serves to objectify the accumulating knowledge of the classroom group. By restructuring school activities so that they focus on that accumulating body of knowledge rather than on subsidiary tasks, we would hope for students to become more responsible agents in the knowledge-building process [6].

We did not prescribe a curriculum or a regimen for using CSILE. Instead, we left the curriculum to the teachers and worked with them to find ways to use CSILE to advance their curriculum objectives. Not surprisingly, this meant that initially CSILE was used mainly as a medium for activities much like those the teachers had used in the past. Over time, the teachers began to modify their curricula so as to take fuller advantage of CSILE capabilities. There were noticeable trends toward longer units that went more deeply into subject matter and toward differentiated activities rather than ones that had all students doing the same thing. At the same time, however, each teacher was evolving his own distinctive approach to structuring student activity in the CSILE environment.

Two models of CSILE use with grade 5-6 students

The two models to be discussed were abstracted by us from observations of CSILE use and the CSILE notes produced by students in the two experimental classrooms. The two models may be briefly characterized as follows:

1. The independent research model. Students work as relatively independent researchers, raising their own questions, seeking answers to them, and reporting what they have learned.
2. The collaborative knowledge-building model. Students jointly plan investigations, assign subtopics or tasks, and comment constructively on one another's contributions.

The independent research model

Alongside the window in which students create text notes, CSILE 1.0 displays a set of "thinking type" icons. These icons, created by an earlier generation of CSILE students, are

intended to encourage deliberate attention to knowledge processes. Different icons represent high-level questions, planning, goals, new learning, and what I know. Before storing a note in the communal database, a student can label its thinking type by selecting the appropriate icon. Other students may then retrieve that note through a search that includes thinking type: for example, "Find notes about explorers and of thinking type new learning."

In the Independent Research model, CSILE activities are structured around the thinking types. In a typical unit, students begin by producing what I know notes, summarizing what they already know about the topic, and high-level questions. "High-level," in this context, refers to questions that do not automatically pop into mind but that come through thinking about the topic. These questions are intended to guide the generation of planning and goals notes, which set out the students' intentions for pursuing the high-level questions. As work proceeds, students produce new learning notes that represent in text or graphic form what they are finding out. Their investigations may also give rise to new high-level questions notes.

Notes of all thinking types go into the communal database and are available for all students to read and comment on. Thus students can comment on one another's questions, goals, and plans, as well as on the more substantive notes. Reading and commenting on others' notes is not an integral part of the Independent Research model, however, and is left to the individual initiatives of the students.

Questions generated by students play a central role in this model, since they are used to guide planning and research. We have done several studies examining the educational potential of questions formulated by CSILE students [6]. Using ratings by teachers and independent judges, it was shown that a sizable percentage of student-generated questions (46% under the most favorable conditions) were judged to have the potential to lead to significant advances in understanding. However, this research identified two different kinds of questions, text-based and knowledge-based. Text-based questions are most often produced when students have access to source materials and when they ask questions that the texts can be expected to answer. Knowledge-based questions arise from something the student wonders or is puzzled about or personally wants to know. Such questions may, of course, be stimulated by reading, but they were found to occur most frequently when students were not primed with informative material but were simply asked to think about a topic.

The intent of the Individual Research model, betokened by the high-level questions icon, is clearly that students should be asking knowledge-based questions. The activity structure, however, is conducive to text-based questions. Because students are expected to seek answers to the questions they generate, there is an incentive to ask questions that they know can be found in the available reference material. In the worst case, this leads to questions that appear to have been produced by turning text statements or headings into questions: for example, "How many babies does a prairie dog have each year?" Usually, however, at least some questions by each student suggest a desire to know or to explain: for example, "Why do prairie dogs live underground?" "Did Marco Polo have any medication?"

Although text-based questions often seem stilted and poorly motivated, they would appear to have value in directing students' attention to the information obtainable from texts rather than passively processing text statements. A number of studies (see reviews -- [5, 11]) have shown gains in learning as a result of teaching students to ask text-based questions. CSILE students in the Independent Research model appear to have become proficient in using such questions without special training. The teacher from whose classroom we abstracted the Independent Research model had not used student questions in teaching before CSILE and was encouraged by the overall quality of the students' work in comparison to earlier years.

Although the Independent Research model relies on CSILE's text, graphics, and storage and retrieval facilities, the communal character of the database is not systematically exploited. Most of what goes on could be done as well with a non-networked system and each student having his or her individual database. Students in the Independent Research model class read only about 70% as many of one another's notes as did students in the Collaborative Knowledge-Building class and made only about half as many comments. Reading and commenting nevertheless went on. Since it was not a formal part of the work, it tended to be spontaneous and to reflect genuine student interests. The outstanding instance was a set of 12 notes and comments, all provoked by a new learning note of one student reporting that sponges have three ways of reproducing. Notes dealt with questions, speculations, and new information about why this was so and, most interestingly, the rather deeper question of why, if three ways of reproducing are good for sponges, other creatures do not have three ways as well.

The collaborative knowledge-building model

The example that ended the preceding section suggests the kind of intrinsically-motivated joint pursuit of a knowledge goal that the Collaborative Knowledge-Building model is de-

signed to foster and to make a common rather than rare occurrence. To this end, much greater use is made of the interactive capabilities of CSILE's communal database. Joint planning, sharing of findings, and commenting and making suggestions to other students are emphasized. Whereas the essence of the Individual Research model is embedded in a sequence of activities, the Collaborative Knowledge-Building model is better represented by a set of principles that apply across all phases of students' work on a unit. These principles are knowledge aggregation, group planning, cooperative pursuit of explanations, and cooperative commenting. Again we point out that the model is abstracted from observations and is an idealization. The principles are not necessarily formulated as such by the teacher but are observed to characterize the form of activity that is encouraged in the Collaborative Knowledge-Building model.

Knowledge aggregation: The sum of students' knowledge in an area is bound to be greater than that of any individual student. In the Collaborative Knowledge-Building model classroom, it is emphasized that students should be learning from what everyone in the class has produced, not just from their own research. To put this idea across to students, the teacher has designed an introductory activity in which, as a homework assignment, each student is required to come to class with one important fact about germs. By the time 30 such facts have been reported and listed, it becomes apparent to the students that they have acquired a great deal of knowledge even though each student has been responsible for only one item of it.

Group planning: Students in the Collaborative Knowledge-Building model classroom generally work on units in groups of 4 to 6. Planning includes dividing up tasks and subtopics. Because CSILE 1.0 permits graphic notes to be linked in downward-branching hierarchies, it is possible for groups to integrate individual contributions by branching them downward from a central chart that serves both as a plan and a unifier. Figure 1 shows portions of such a branching network. It began with the group choosing the kitchen scene produced by one of their number as the centerpiece of a project on fossil fuels. They then distributed the task of producing subcharts showing the many ways in which fossil fuels are used in a kitchen. The resulting production constitutes a hypermedia document conveying the aggregate of findings from the students' individual efforts.

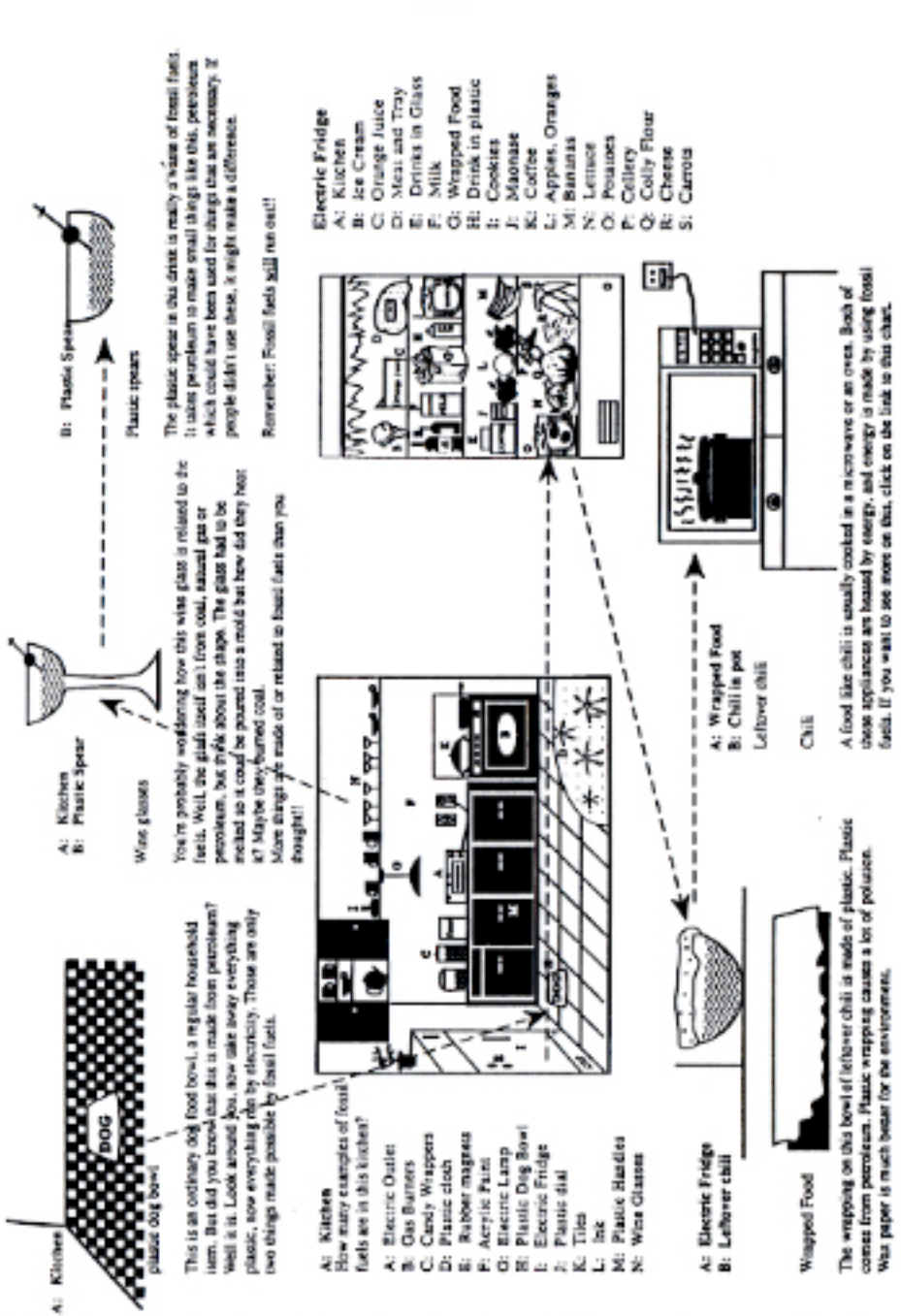

Figure 1: Cooperative elaboration. Students elaborate the theme of fossil consumption by producing charts hierarchically descending form a parent chart (kitchen scene). Each chart (only a few examples shown) explains how fossil feuls are used in relation to the selected object. All texts and drawings are original.

Cooperative pursuit of explanations: Miyake [4] has shown with college students that, when they work in pairs, one tends to push the other toward deeper levels of explanation. In CSILE 2.0 we will try to provide environments specifically to support this kind of ratcheting progress toward deeper explanation. In CSILE 1.0, however, searching and commenting serve this purpose in a less organized way. In one instance, several students became involved in trying to work out an explanation of the diaphragm and its role in hiccuping, sneezing, and laughing. By reading and commenting on one another's notes, the students came to see the interrelatedness of these phenomena, and this led them to raise and consider a deeper question: Since the mechanisms of hiccuping, sneezing, and laughing are similar, what explains the differences between them? This question reflects a striving for coherence that is vital in science [10] but rare in children. It is doubtful if it would have arisen without the cooperative activity.

Cooperative commenting: When students sign on to CSILE they are notified of and given the chance to retrieve any new comments that have been made on any of their notes. Comments thus have high saliency, and this may explain why, even in the Independent Research model classroom where commenting is incidental, 13% of the text notes produced are comments. (The corresponding figure for the Collaborative Knowledge-Building model classroom is 22%.) Commenting is an expected part of student work in the Collaborative Knowledge-Building model classroom, comments are monitored by the teacher, and students are coached in ways to make their comments constructive and helpful. As mentioned previously, students in the Collaborative Knowledge-Building model classroom produced twice as many comments as those in the Independent Research model classroom.

Empirical analysis of differences between the two models

Quantitative differences in CSILE activities

Tracking facilities in CSILE 1.0 make it possible to compile information on student use of CSILE's various functions. These data allow us to investigate whether students in the Independent Research model and Collaborative Knowledge-Building model classrooms behave differently in ways consistent with the two models. Table 1 provides frequency data for a variety of aspects of CSILE-related activity. In this section we will examine differences in

mean frequencies. In a later section we will examine patterns of correlation between these frequency variables and educational outcomes.

In Table 1 tracking variables are grouped into four categories that will be used later in regression analyses: Productivity, Exploring Work of Others, Collaborating, and Advanced Knowledge Processes. Significant differences were found between model classrooms in every category. With one exception, differences were all in the same direction, reflecting an overall higher level of CSILE use in the Collaborative Knowledge-Building model classroom. The exception was in the length of text notes. Although the two classes did not differ significantly in the number of text notes they produced, notes by students in the Independent Research model class averaged almost 40% longer.

Table 1
Means and Standard Deviations of Selected Tracking Variables

	Class				
	Independent Research Model (n=22)		Collaborative Knowledge Building Model (n=28)		Significance level for difference between models
	M	SD	M	SD	
Productivity					
· total number of text notes	40.64	14.43	46.50	18.91	n.s.
· total number of graphic notes	13.59	6.79	27.07	13.55	$p < .01$
· total number of hours in the graphics program	20.29	17.78	39.31	33.49	$p < .01$
· average number of words written in text notes	120.33	32.47	86.31	18.92	$p < .01$
Exploring the work of others					
· searching for notes by others	55.05	31.04	66.50	29.70	n.s.
· reading notes written by others	108.18	77.16	151.64	80.08	$p = .06$
Collaborating					
· number of comments	5.23	3.35	10.07	5.42	$p < .01$
· average number of keywords per note	1.14	.17	2.34	.56	$p < .01$
· number of topics	21.18	12.68	39.21	14.87	$p < .01$
· number os links to other students' charts	.27	.77	2.18	2.02	$p < .01$
Advanced knowledge processes					
· thinking types	7.05	5.46	23.50	13.49	$p < .01$

The results shown in Table 1 are consistent with the overall higher use of the networking capabilities of CSILE by the Collaborative Knowledge-Building model group, its greater use

of linked graphics as a means of organizing cooperative work, and the greater emphasis in the Independent Research model classroom on individual documentation of learning.

Differences in educational effects

Data on educational effects were collected not only in the two CSILE classrooms but also in a comparison class in another school, also taught by a male teacher of similar experience, and with a student body fairly similar to that in the CSILE school, although they were in a suburban area of somewhat higher socio-economic status.

Constructive effort and knowledge quality. At the end of a science unit, writing samples (handwritten by all groups) were produced in response to the prompt: "What I have learned from doing this unit." Two raters, blind to condition, rated each essay on 15 indices, which were then collapsed into two composite variables: Constructive Effort and Knowledge Quality. Analysis of variance showed highly significant differences between groups on both variables. However, post hoc tests showed in each case that the only significant pairwise difference was between the Collaborative Knowledge-Building model class and the control. These results must be viewed with caution because the topic of the science units varied and there was a delay in administration of the writing task to the Independent Research model class, which may have worked to the disadvantage of that class.

Question-asking. As noted previously, the ability to ask educationally productive questions plays an important role in CSILE, especially in the Independent Research model. To evaluate this ability, we asked students to write questions on a topic being studied. Before study began they were asked to generate questions about "What I wonder about (the topic)." At the end of the unit they were asked to write questions on "What I now wonder." These questions were rated on a scale ranging from asking about isolated facts (at the low end) to asking for explanations (at the high end). Analysis of variance again showed significant group differences, and post hoc comparisons showed the Collaborative Knowledge-Building model class to be significantly higher than both the Independent Research model and control classes in tendency to ask questions of explanation.

Standardized achievement test scores. In October and again in June, students completed the Language subtests (Vocabulary, Reading, and Spelling) of alternate forms of the Canadian Test of Basic Skills, a battery similar to the California Test of Basic Skills. Analysis of variance showed significant group differences in gains, which were largely accounted for by the Independent Research model class gaining significantly more in Vocabulary than either of the other two classes.

Relations between tracking data and educational outcomes

To investigate the relationship between how students use CSILE and educational outcomes, we used stepwise multiple regression analyses. The independent variables or predictors used in the analyses were composites representing the four classes of variables shown in Table 1, plus Initial Status, a composite formed from age and average grade-level scores on the mathematics and language sections of the achievement pretest. Dependent variables investigated were Constructive Activity, Knowledge Quality, and Language Achievement Gain. Initial Status was entered into the stepwise analyses first, on the premises that it would account for significant variance in any learning outcome and that this variance should be controlled before looking for additional predictive variables. Separate analyses were performed for the two CSILE classrooms.

Table 2
Regression of initial status and tracking variables on knowledge quality.

Regression of 7 Predictors on knowledge quality	independent research model			collaborative knowledge building model		
Variable entered	R^2	inc.	sig. of inc.	R^2	inc.	sig. of inc.
Initial Status (age, math, language)	.14	.14	n.s.	.25	.25	.07
Productivity	.31	.17	.05	.25	.00	n.s.
Exploring work for others	.35	.04	n.s.	.38	.13	.04
collaborating	.45	.10	n.s.	.51	.13	.03
advanced process	.60	.15	.04	.52	.01	n.s.
Overall significance of 7 predictors		p = .04			p = .02	

With respect to Language Achievement Gain, Initial Status was the only significant predictor in either class. With respect to Constructive Effort, there were no significant predictors in the Collaborative Knowledge-Building model class, but in the Independent Research model class Advanced Knowledge Processes contributed significantly to prediction. With respect to

Knowledge Quality, an interesting pattern emerged. As shown in Table 2, there was significant prediction overall in both classes, but the significant predictors were entirely different. In the Independent Research classroom the two significant predictors of Knowledge Quality were Productivity and Advanced Processes (which was indexed by amount of use of Thinking Type icons). In the Collaborative Knowledge-Building classroom the significant predictors were Exploring and Collaborating--the two measures of communal activity. These results are strikingly 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, and the more interactive kinds of CSILE activities are irrelevant. 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 cooperative activities.

Conclusion

Because, from an experimental design standpoint, the two models of CSILE use are thoroughly confounded with teacher differences, it is risky to infer causal relations. The patterns of process, outcome, and correlational results are, however, highly consistent with model differences. These results suggest that a Collaborative Knowledge-Building model of communal database use does indeed foster more exploratory and collaborative uses of the database, leading to a higher quality of knowledge development. An Independent Research model, on the other hand, fosters more writing, possibly reflecting more use of external information sources, and this in turn may account for superior gains in vocabulary.

Both models represent a reorientation of education, away from activities and toward knowledge as the focus. Only the Collaborative Knowledge-Building model, however, involves radical restructuring in the direction of making classes into knowledge-building communities. It should be clear that our bias is toward that model. It is the model CSILE is designed to support, and our continuing effort in designing future generations of CSILE is to provide stronger support for collaborative knowledge building. The Independent Research model has the advantage that, since it does not depend on a communal database, it could be implemented with a non-networked system using conventional software. We suggest, however, that a networked communal database may have a significant role to play even in the

Independent Research model, as shown by the amount of reading and commenting on other students' notes in the Independent Research model classroom.

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