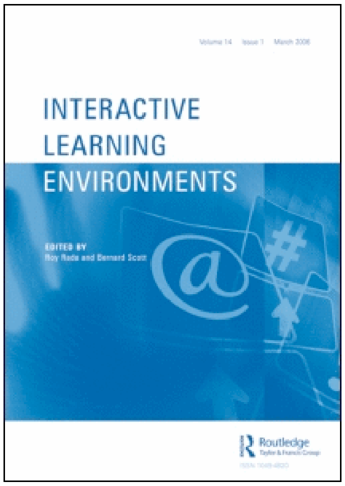

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Discourse *About* Ideas: Monitoring and Regulation in Face-to-Face and Computer-Mediated Environments*

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ABSTRACT

In this paper we analyze the collaborative activity of grade 5–6 students as they work on computer-simulated physics problems. We compare two groups, both similarly supported in a basic science-discourse structure, but with that structure embedded in different contexts. The first context is face-to-face, small-group interactions; the second is face-to-face and CSILE (Computer Supported Intentional Learning Environments) interactions. The CSILE interactions place emphasis on individual contributions to a communal effort. We show that CSILE has special affordances for active monitoring and regulation of students' own and others' ideas and actions. Accordingly, dividing time between asynchronous CSILE work and face-to-face conversation should result in more monitoring and reflection of ideas than face-to-face interactions alone. Ten groups of three students each worked for 12 weeks on a unit, "Gravity and the Solar System," designing experiments and testing hypotheses on two problems: "What affects how things fall?" and "What affects the path of satellites/comets?" Analyses of videotape recordings and transcripts of conversations indicated that in the CSILE plus face-to-face condition, as compared to the face-to-face only condition, students engaged in more reflective activity. CSILE's affordances for monitoring and reflection appeared to be responsible for a more even distribution of contributions and greater attention to and productive use of the ideas of collaborators.

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INTRODUCTION

Scientists monitor and evaluate the work of collaborators and engage in interchanges that facilitate progress within their local scientific community (Dunbar, 1995). The present research seeks to understand ways in which collaborative computer environments might enhance monitoring and evaluation of the work of collaborators in the service of knowledge advancement. Our analysis considers the interweaving of oral and written modes of collaboration, individual and group processes, synchronous and asynchronous communication, and computer-mediated and face-to-face collaboration. These are examined through a comparison of small groups carrying out collaborative inquiry under two conditions. One is a face-to-face condition, in which the group members work together at a computer workstation and carry on their planning, interpretation, and so on orally. In the other condition, group members work side-by-side but at different computers, and their discourse is divided between oral communication and written communication mediated through a CSILE client-server network.

Conversations around the computer represent significant learning moments, and it has been argued that wise classroom design would have students clustered around a single computer rather than working separately (Bruce & Rubin, 1993). Separate computers, according to this view, lessen opportunities for peer interaction and discourage consensus-making efforts. This assumption is inherent in the arrangement of typical technologically advanced North American classrooms, where students use computer technology to simulate laboratory experiments (e.g., Howe, 1990; Pea, 1991a) and have small groups of students gather about one computer running a science microworld. Students attempt to construct their understanding of concepts directly from their interactions with and about the simulation.

Research suggests that the interchanges that result (1) foster progressive scientific discussion among students about what will happen (Howe, 1990), and (2) promote conceptual change and improved understanding when the small groups comprise students with differing preconceptions or ideas about the concepts represented (Howe, 1990). These and other research findings also suggest limitations with this arrangement. In unstructured conversational interchanges, students' investigations center around outcomes rather than systematic efforts to understand concepts (Schauble et al., 1991); and students often have similar preconceptions about a phenomenon, which makes it less likely that talk alone will advance their understanding.

There are other, more global problems with classroom conversations that need to be addressed if we are to support more reflection through them. In contrast to written text, the more ephemeral ideas of conversation make review and revision of ideas relatively difficult, and the fast pace of conversation favors presentation of ideas in forms that come to mind quickly. Classroom talk is especially limiting of reflective thought, with the average time provided for response after a question is asked a few seconds (Dillon, 1982). Yet another problem with classroom conversations is dominance hierarchies (Cohen, 1991). There are talkers and non-talkers, and the ideas of more outspoken contributors tend to be the dominant ones in conversations.

In an effort to enhance learning from computer simulations, experiments in restructuring discourse surrounding the use of microworlds or other computer-presented scientific material have been conducted. For example, researchers have provided a structure that requires students to collaboratively plan experiments, predict outcomes, reconcile outcomes with predictions, and form conclusions (Linn & Burbules, 1993). This kind of a structure improves students' integration of data with their theories, facilitating more general, scientific understanding. For the rest of this paper we refer to the combined use of microworlds, specially designed discourse supports to enhance group work, and resultant conversations as the *face-to-face* condition. The scientific structure of the discourse is supported through a *proforma* described below.

We contrast this enhanced face-to-face condition with a CSILE condition that makes use of the same proforma but embeds it into the discourse around the computer simulation activities in a different way. CSILE (Scardamalia & Bereiter, 1994) is a software environment that provides means for students to produce, share, and comment on notes that are entered into a communal database. It also provides scaffolds for the construction of various kinds of note content in the form of labels or phrases assigned as note attributes. For the present study, the elements of the proforma were introduced into CSILE as scaffolds. Our attempt was to achieve "the best of both worlds" by combining the recognized advantages of small-group oral discourse and the opportunities for independence and reflection afforded by the CSILE medium. It was also anticipated that the CSILE condition would lessen the dominance relationships that result when face-to-face communication is the primary mode of interaction.

In the present experiment we controlled the total amount of time committed to negotiating ideas. Since that meant that time spent in CSILE was time taken away from oral discussion, it is not obvious that the combined approach should yield superior results. Indeed, claims for the value of teams working together at computers and negotiating their actions and conclusions would argue for the superiority of the face-to-face only approach. In the following sections, however, we present a rationale for predicting that in the CSILE condition students would engage in self-monitoring, *as well as* more monitoring of others' goals, and that they would show more reflection than students in the face-to-face condition.

Metaprocesses

Flavell (1981) offered a model of cognitive monitoring, highlighting metacognitive strategies used to monitor one's own cognitive activities. Brown (1978) identified two types of metacognitive knowledge: knowledge about cognition, and knowledge about regulation of cognition. Knowledge about cognition is stable, fallible and rather late in developing, and is necessary for reflecting on the products of one's cognitive activity. Knowledge about regulation of cognition is used to regulate and oversee strategic action such as planning, checking and monitoring of cognition. Brown further argued that self-regulation is a necessary component of active learning.

Bereiter and Scardamalia propose an account of expertise in which regulatory processes form the basis of continual improvement (Bereiter & Scardamalia, 1993). Expertise is an extension of the processes of intentional learners (Bereiter & Scardamalia, 1989), viewed within broader social contexts. Mindfulness (Salomon & Globerson, 1987) is another construct that has been used to characterize the special and powerful monitoring and regulatory processes deemed central to effective learning.

In all of this work there is attention to social processes. Dunbar (1995) described one example of the social basis for cognition. In a study of research scientists' individual and collaborative activity, he discovered that the way unexpected data were related to hypotheses differed depending on whether the scientist acted alone or within the research group. If the scientist was alone, the unexpected data were generally attributed to experimental error. However, if the unexpected data were presented in a research meeting, other scientists tended to monitor the experimental process, assessing whether it was flawed. If it was not, the unexpected data generally forced a revision of the hypothesis. This process illustrates the critical role of collaborative settings in monitoring and regulatory processes. However, it is not only beneficial to monitor and regulate cognitive processes, one must also attend to overt processes.

An extension of metacognitive processes to the monitoring and regulation of procedures, or *metaprocedural processes*, was discussed by Karmiloff-

Smith (1992). Metaprocedural processes occur when procedures originally intended to operationalize goals become the input to discourse about procedures. Metaprocedural processes are important, for example, when one is planning and conducting experiments, or when the discussion is about one's own or others' experimental procedures.

For Dewey (1933), monitoring and reflection are part of the same fabric. The interconnectedness of these processes and their role in advancing the thinking of young students was demonstrated in a study of written composition (Scardamalia et al., 1984). Writing generally has been viewed as a medium for reflection, with inherent supports for monitoring ideas (Olson, 1994; Bereiter & Scardamalia, 1987) making writing a potentially powerful metaprocedural medium.

Below we discuss efforts to enhance schoolwork by adding a reflective layer to school tasks. The work reported serves as a backdrop for our own efforts with Computer Supported Intentional Learning Environments (CSILE). Our goal in the design of CSILE is to restructure classroom discourse (Scardamalia & Bereiter, 1992; Scardamalia & Bereiter, in press) and to enhance self-regulatory processes and make them an integral part of school life. New knowledge media help make this possible, and the experiment reported here represents our effort to clarify issues central to the design and use of knowledge media to support metaprocesses.

This study investigates the hypothesis that the distinctive contribution CSILE makes results from increases in self- and other-regulation. Before elaborating this hypothesis, we look briefly at efforts to enhance face-to-face conversations, as CSILE's presumed role in preparing students to better engage in face-to-face conversation is part of what is at issue.

Reflective Processes in Conversation

A study of conversational interactions of intentional learners was conducted in a class of adult Anglophones studying French, and was made possible by each student agreeing to wear a microphone and to think aloud while engaged in French lessons. Students whispered their thoughts into the microphone at times when they were not directly engaged in the interchanges, so thoughts surrounding interactions, as well as direct contributions to those interactions, were recorded (Corbeil, 1989).

Results showed that the highly intentional minority members of the group treated every interaction as if it were directed personally at them. Accordingly, in the seconds before and after someone was called on to respond to a question, the intentional learner constructed a response. After the intended respondent replied, and the response was elaborated, the intentional learners reviewed data from all sources, making a mental note of what they had learned from their own and others' engagement in the interchange. For the less intentional students, the times surrounding their direct engagement in conversation was far less productive, marked either by no evident mental activity, off-task activity, or anxiety (conveyed through statements such as "Oh, I hope she doesn't ask me to answer!").

This experiment demonstrated how highly intentional learners do much of what is hypothesized to occur through writing. First, they construct an explicit, individual response, against which other input is contrasted. In doing so they dramatically increase the time committed to learning, using every classroom interchange as an opportunity to build their knowledge, rather than waiting for "their turn." Second, they do work mentally that might be done with greater ease and perhaps more precision if there were written records, as these would make it easier to reflect on the contributions of all group members and lessen memory demands associated with needing to keep everything in mind.

CSILE aims to provide for all students the personal time and space that these highly intentional learners find for themselves in conversations. Whether CSILE participants work at the same or different times, from the same or different locations, or enter single notes or add to group discussions, they contribute their own, as well as group-produced entries. These are contributed to a common forum where they then serve as objects for further inquiry. In face-to-face interactions the work of intentional learners is not available to the whole community; it is limited to the silent and private reflections of select participants. CSILE is designed to increase chances that the ideas of these participants will be recorded and available to others; at the same time it provides those who might not otherwise contribute with time to do so. If CSILE accomplishes this, we should see advantages along the following dimensions:

- Monitoring own ideas
- Monitoring ideas of others
- Co-ordinating the ideas of all participants to create a more integrated framework for their work

We hypothesize that students using CSILE will move further along the metaprocedural dimension from self-regulation to other-regulation than students using enhanced face-to-face interactions. The CSILE students were not provided more time to do additional layers of activity, but rather had to split their time between the quiet moments in which they worked alone and the more interactive consensus-making time. The face-to-face students, in contrast, were more actively engaged in conversations at all points in the process.

More personal ideation, with subsequent reflection in light of the work of others, should be favored by having students record their own, separately developed ideas. This situation is fostered in the CSILE environment in which each student has personal space embedded in a communal workspace. Accordingly, each participant needs access to a computer, just as each participant of a conversation needs to be co-present. The interaction of synchronous and asynchronous processes that we aim to achieve with the CSILE condition is much like that of the highly intentional learners who combine independent and interactional processes in the course of face-to-face conversations. It was accordingly hypothesized that the combination of individual plus collaborative workspaces and the permanent and retrievable nature of ideas afforded by CSILE would enable more effective oral interchanges about students' ideas and experiments, resulting in an increased level of metaprocesses in the CSILE condition.

METHOD

Subjects

Thirty students of one intact grade 5–6 elementary classroom participated in this study. The students were from a middle-class, urban elementary school. The class was part of the ongoing CSILE research program. Students varied in their experience with CSILE. All of them had been using CSILE regularly for the preceding 6 months, but almost half the class had also used CSILE in one or more previous years. The teacher had over 5 years' experience with CSILE.

Materials

Computer equipment

All experimental work took place in a classroom with eight networked Macintosh II computers, all with fourteen-inch color displays, and one server, a Macintosh Quadra. The computers were in the classroom and were networked using Ethernet and running the Macintosh Operating System, version 6.1.7.

Physics simulations

As noted above, this research took place as part of the unit, Gravity and the Solar System. Within this unit, experiments and exploration were carried out on two problems: "What affects how things fall?" and "What affects the path of satellites/comets?" Computer simulations for each problem were developed by the first author using the simulation package, Interactive Physics™.

Network software

CSILE, a client-server collaborative database system, was running on all computers. The CSILE "theory" scaffold was replaced by a scaffold—hereafter electronic proforma—designed to support scientific discourse around experimental work. The proforma supported students in writing notes about goals and predictions for their proposed experimental work, recording experimental tests and results, and producing summary statements of what was learned from the experiment.

Pencil-and-paper proforma

In the face-to-face condition, students had a folder of pencil-and-paper proformas, forms on which students could record the same information as the students in the CSILE condition. For the rest of this paper this form will be referred to as the *pencil-and-paper proforma*.

Recording equipment

All of the sessions were both audio- and video-recorded. Each of the members of a group had a lapel microphone. The video was a standard VHS system while the audio portion of the video used a proximal zone microphone (PZM).

The Experimental Setting

For the CSILE condition, the students worked in groups of three and each student had access to a computer. The computers were all running the physics-simulation environment and CSILE. The electronic proforma was accessed from within CSILE. The students were seated next to each other. For the face-to-face session, all students gathered around one Macintosh running the physics simulation and had a folder of pencil-and-paper proformas.

Design

All students worked on the problem "What affects how things fall?" first, and "What affects the path of satellites/comets?" second. Half the students worked in the CSILE condition first and the face-to-face condition second; the other half worked in the opposite order. The design is an incomplete between/within design with two factors, (1) discourse framework: CSILE/face-to-face, and (2) problem, “What affects how things fall?” and “What affects the path of satellites/comets?”. This design allows us to assess the affordances of CSILE and face-to-face conditions with respect to metaprocesses.

PROCEDURE

Overview

The experiment was carried out over a twelve-week period. In that time, the students were assigned to groups, learned to use the simulations and enter data and ideas into the proforma, and had three experimental sessions on both problems: “What affects how things fall?” and “What affects the path of satellites/comets?” (students choose to focus on either comets or satellites in the second problem).

Assignment to Groups

Thirty students worked in groups of three. The students chose their own groups with minor adjustments from their teacher. Group membership was fixed over the course of the investigation. Five of the ten triads were randomly assigned to each of the two discourse framework conditions.

Practice

All the students were introduced to simulations and procedures by the first author and the teacher for the physics problem using a pre-experimental simulation on “What affects the time of the swing of the pendulum?”. Each group had one training session in using the simulation, setting variables, reading times and resetting the simulation and completing proformas. Each group also had two experimental sessions with the pendulum problem, one with CSILE and one in the face-to-face condition. Each session lasted between 35 and 45 minutes. There was a minimum of 24 hours and a maximum of 3 days between sessions. All groups went through the same procedure using identical materials.

CSILE Condition

For the CSILE condition, students used CSILE to record, store and retrieve all their work. The students worked for three sessions, each lasting between 35 and 45 minutes. For the first two sessions, the students started each session with one, consensual, high-level goal. Subsequently they each planned, made predictions, executed experiments, and explained what they had learned. Finally, each of the first two sessions ended with students developing one consensual conclusion. The third session was the same, but at the end, rather than writing a conclusion for the session, the students completed a consensual conclusion and synthesis of all three sessions. They articulated and individually entered their plan and prediction into CSILE. They did so on their own computer, sitting near their collaborators. Experiments were conducted using the simulations described above. The students worked together as they chose (i.e., they could work alone or collaboratively). Oral exchanges were frequent and important in completing the problem. The teacher was available to answer conceptual (physics) questions in both conditions. All sessions were both video- and audiotaped by the researcher.

Face-to-Face Condition

In the face-to-face condition, the same procedure was followed with the following exceptions: the students used the pencil-and-paper proforma to record their plans, predictions, experimental test results, and summaries; and, they jointly ran experiments and entered information arrived at through consensus into proformas.

Data and Measures

The data came from the transcribed oral discourse of the students while they were doing their experiments in CSILE and in the face-to-face conditions.

Unit of Analysis

In order to score the oral discourse, transcripts were parsed according to the type of operation in which the students were involved. A simplified notion of exchange structure was used. An *exchange* was defined as an initiation plus all the utterances following until another initiation occurs. Inter-rater agreement was over 83% for two independent raters on over 25% of the dataset, randomly selected for analysis to assess reliability.

A first-pass on each oral exchange was used to extract the metaprocedural content of students' discourse. To accomplish this, each oral exchange was categorized as metaprocedural (monitoring, reflecting, and coordinating work to set up and interpret experimental tests) or other (social interchanges, repeating instructions, or off-task activity). Inter-rater agreement was over 87% for two independent raters on over 25% of the dataset, randomly selected for analysis to assess reliability.

Metaprocess Analysis

The oral discourse exchanges that were scored as metaprocess oriented were broken down into three categories corresponding to those presented in the introduction to this paper:

- Monitoring own ideas
- Monitoring ideas of others
- Co-ordinating the ideas of all participants to create a more integrated framework for their work

Inter-rater agreement was over 89% for two independent raters on over 25% of the dataset, randomly selected for analysis to assess reliability.

Below we present selected sections of discourse to illustrate the metaprocesses of interest. Quantitative data on a larger dataset is presented in a subsequent section after case-study data are elaborated.

Examples of Student Discourse

The discourse presented is from one group of three students, working first in the face-to-face condition on the problem "What affects how things fall?" for the face-to-face condition, and "What affects the path of the satellite/comet?" for the CSILE condition. Each student's name has been replaced with the letter A, B, or C. The relationship between the letter and the specific student is preserved as these students move from the face-to-face to the CSILE condition. The discourse is presented as related sets of face-to-face exchanges separated by a blank line (sequences) with a short description/discussion of each sequence and the proforma entry (if any).

Face-to-Face Interchanges

In the following excerpt, the group is beginning a new trial for the experiment on shapes. Note C's direct use of proforma questions (in bold) to structure the discussion. B responds with a comment specifying the causal variable, *shape,* which the group plans to test.

1 C OK. Let me try to find it. OK. **What are we trying to find out?**
2 B What are we trying to find out? We are trying to find out if the . . .
3 B The shape affects the speed that it has.

4 B If the speed affects it.
5 B We are trying to find out if the shape affects the speed of the object.

{Entry into the proforma: *If the shape affects the speed of the object}*

In the second excerpt, they are completing one trial and moving on to another. B proposes that mass is the causal variable (1). In the second and third exchanges, B reports the result. In the last exchange, C begins again with a proforma statement (7). He begins to attempt to explain his idea but stops. B is able to report the result, then reconceptualize that knowledge as relevant to their current problem. C has the proforma, but B dictates to C what to write in the proforma (*The smaller the object the faster it goes*).

1 B You know it is the mass that is affecting.

2 B 0.42.

3 C Oh, 0.42?
4 B 0.43
5 A 0.43, that is what I meant.
6 C 0.43

7 C **What have you learned from this experiment?**
8 C . . . Or the mass affects . . . the mass. The slower . . . *the faster it goes.*
9 B Mass is smaller the . . . *the smaller the object is . . .*

{Entry into the proforma: *The smaller the object the faster it goes*}

These passages are notable in two respects: (a) In many of the sequences, students A and C use the proforma (which has the prompts “What have you learned from this experiment?”, “What are we trying to find out?”, “Explain what you think will happen”) to initiate or structure the sequence. The response to the prompts often involves a statement of factual knowledge followed by an explanation. The proforma mediates the structure of the discourse. There is no high-level discussion between either B or C and A. However, C helps B to construct the explanation “*The smaller the object the faster it goes*”; B makes almost all the utterances with explanations. B keeps discussion directed toward understanding, while A interacts little or not at all with B or C. The students seldom considered each other’s ideas, or worked to integrate or build on these ideas.

CSILE-Supported Interchanges

The following oral discourse occurred at the beginning of a session in which students were establishing individual goals and experiments. Student B monitors what the others are doing (1), and attempts to monitor whether a particular type of experimentation is going on (3 & 4). Next, the three students are trying to coordinate their work (6 on). In particular, student B helps ensure that they are not duplicating past work, and that they distribute responsibilities in moving toward their overall goal.

1	B	So what are you guys trying to do?
2	C	What?
3	B	Are we all going to be doing the same experiments?
4	B	Are we all going to be doing the same experiments? Or . . .
5	A	We are not going to do the exact same.
6	B	C, why don't you try to find out if the speed causes the satellite to go into the planet. And A try . . .
7	C	Direction. I will try direction.
8	B	Direction.
9	B	And what should I try? Mass? I will try mass.
10	A	Okay.
11	B	Mass of the satellite.
12	A	Okay, then I have to change the direction. I will just leave it always at north.
13	C	No, I am doing the direction.
14	A	I know. (separated)
15	B	Actually A, we know that if the direction. . .
16	C	Yes . . .
17	B	We know the speed and direction so I will have to try mass and . . .
18	A	I will do mass of the planet.
19	B	I will do mass of the satellite.
20	C	Then what do I do?
21	C	I will do the direction.
22	B	Direction? Okay.

Following this interaction, A goes on to do a series of experiments on the planet mass, B performs a series of experiments on the mass of the comet, and C does a series of experiments on direction.

In the next excerpt, A has completed three trials. From the first to the second trial he varied only the mass of the planet. He reported different results (the first went into the planet, the second made an elliptical orbit). Between the second and third trials he changed the planet mass back to earth and increased the speed of the orbit from 4.8 to 10 rotations per day. Then A reported that the satellite went into space. Orally, A reports his results (1), that the mass does not matter; B responds that the results were different in the two trials of the experiment (3). Further, B leads A through the steps needed to get there (4 & 5). When A reports that he changed the speed, B responds by explaining that one must control all the variables but one, or else "it will be a completely different effect" (9 & 10). Here we can see the pursuit of individual goals, a visible trace of lines of reasoning, and a record of experimental trials. A's work is visible to B and available to all parties participating in the database. This is exemplified in the students' discussions about whether or not mass matters. As a result of this interaction, B, after looking through A's experiments, explains to A that he did change the mass and therefore the mass matters. So we can say that B's monitoring of A led A to change his judgement, making progress in their joint understanding.

1 A It's not the mass, really.
2 B But it collided the first time, and the second time it went right around.
3 A That might have been just because of something else I did.

4 B What did you do?
5 B Did you change anything the second time except the mass?
6 A Okay, this is what we can do. Same thing for distance.
7 B Yes.
8 A Same thing for . . . oh, speed.

9 A It could be the speed does affect it.
10 B Did you change the speed?
11 A Yes.

12 B You shouldn't have done that. You should have kept them the same all through the experiments except for the mass. Because it will be a completely different effect.

13 B You definitely changed the mass. I think the mass affects it.
14 A Yahoo!
15 B A lot?
16 A Yes, if it is the planet.

In the CSILE examples, the structure of discourse is quite different from the face-to-face discourse (of course the excerpts were chosen to exemplify such differences). Student B is either monitoring others' oral and written discourse or commenting on their individual actions. In CSILE, students can pursue individual experiments, leaving a trace of that process. Their actions are visible to the other members of the group. Students can benefit from monitoring others and from being monitored. The second example is particularly illustrative of this phenomenon. Student A had performed controlled experiments on speed and mass. However, it was difficult for him to interpret the data. When A made a claim which was incorrect, B could view A's work and help A walk through the data and rework his interpretation.

These examples illustrate the function of oral discourse in the face-to-face and the CSILE conditions. In the face-to-face condition, B dominated the discussion, contributing the only explanation by proposing the control-of-variables scheme and proposing the explanations about causal variables. C only occasionally contributed, and A contributed little or no discourse. In a sense, the session progressed along B's proposed goals and his proposed experiments. In addition, there was heavy use of the structure of the proforma in the students' discourse. The proforma language was appropriated in the students' discourse to structure their sentences rather than to facilitate reflective inquiry.

In contrast, with CSILE mediated discourse, we see efforts to coordinate work and to ensure goals are complementary rather than redundant. In addition, the proforma was used to enable individuals to record and make available their ideas and actions, providing permanent and retrievable records of those ideas.

These students did not elaborate personal goals and experiments in the course of face-to-face conditions, nor did they reflect on others' ideas and data, insofar as these activities could be determined in the metaprocess analyses that we conducted. In line with our predictions, the case additionally suggests that the face-to-face condition brought with it more interchanges in which certain participants dominate the interaction; whereas these same participants in the CSILE condition work more interactively and productively with group members.

In order to test our predictions, it was necessary for the students in the CSILE condition to work independently at a computer, while the students in the face-to-face condition have conversations around a single computer. We argue that the differences found rest with the cognitive processes that are supported. It would be possible to have used a single computer in each condition, and have students take turns using CSILE, so that each individual has time alone as well as group time. But this interrupts the finely-tuned movement between individual and group processes that we wish to encourage. The procedures we are testing may have implications for the number of computers in classrooms. However, our goal has not been to address this issue, but rather to demonstrate conditions under which it is possible to maximize benefits of both computer and conversation time, and to test the specific hypotheses that follow from our theoretical framework.

Quantitative Analysis of the Dataset

This section compares the oral discourse of the students in the face-to-face condition with that of students in the CSILE condition, analyzing the proportion of metaprocess exchanges for each group. A comparison of means using a paired *t*-test revealed that, in the CSILE condition, as compared to the face-to-face condition, there were more exchanges scored as metaprocedural—$t(7) = 2.36$, $p < 0.03$ (Fig. 1).

The role of the proforma was examined across the two conditions to determine if it influenced oral discourse. Each time the student used proforma terminology, either repeating or paraphrasing a statement from the proforma (as opposed to contributing a statement of their own), they were scored as using proforma terminology. The score was the proportion of oral exchanges for each group scored as proforma terminology. An analysis revealed that there was a marginally significant trend toward more proforma terminology in the face-to-face condition—$t(7) = 2.36$, $p < .088$ (Fig. 2).

To examine whether the monitoring of others' ideas that we saw in the CSILE example reported above was a general feature of the CSILE condition, metaprocess exchanges were divided into the three categories set out in the introduction (monitoring own ideas; monitoring ideas of others; coordinating the ideas of all participants to create a more integrated framework for their work).

The score was the proportion of exchanges for each category. The analysis showed that there were similar amounts of self-monitoring in both conditions, and little coordinating of others in either condition. However, there were significantly more events where one member of the group monitored another's ideas or actions in the CSILE as compared to the face-to-face condition — $t(7) = 77.2$, $p < .01$ (Fig. 3).

In summary, there is a higher proportion of metaprocess oriented exchanges and a lower proportion of proforma-statements in the CSILE condition than in the face-to-face condition. Additionally, an investigation of monitoring activities indicates that students are more likely to monitor others' ideas and experiments when using CSILE. In the face-to-face condition, they are more likely to monitor their own ideas and past work.

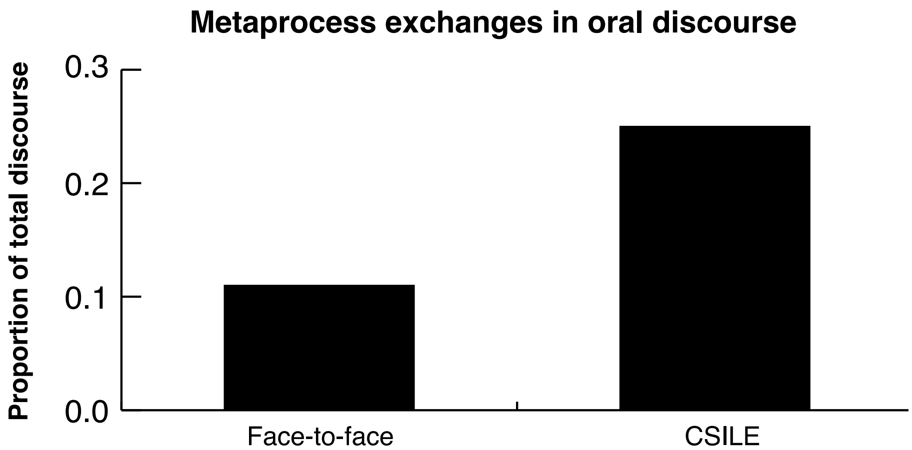

Fig. 1. The proportion of metaprocess exchanges in oral discourse in face-to-face and CSILE conditions.

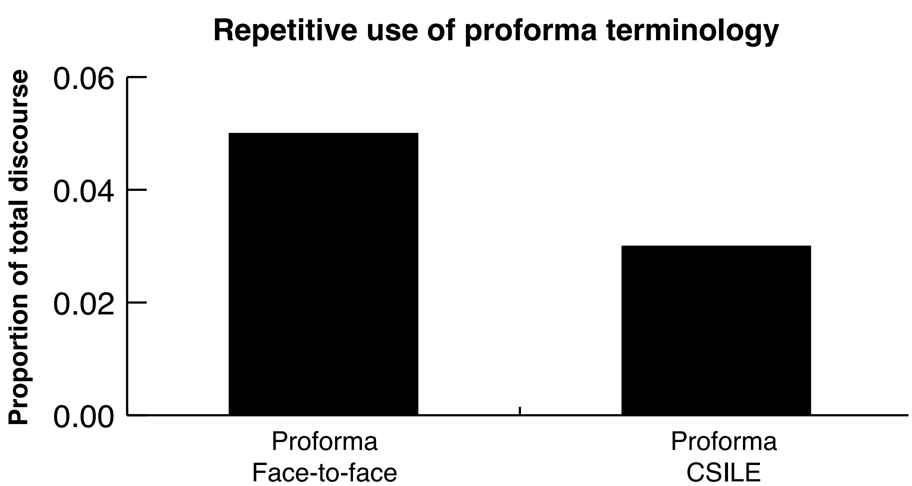

Fig. 2. The proportion of proforma terminology in oral discourse in face-to-face and CSILE conditions.

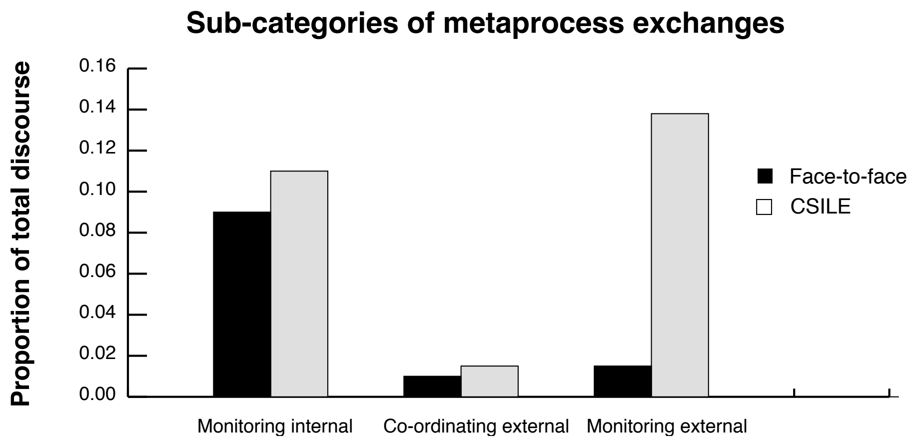

Fig. 3. The proportion of metaprocess oral discourse viewed by sub-category in face-to-face and CSILE conditions.

DISCUSSION

Quantitative data support case-study results, suggesting differences between the face-to-face and CSILE conditions. In the face-to-face condition, students reviewed their own ideas, but there was little evidence of students monitoring others' ideas or actions. The proforma proved to be more of a crutch than a facilitator of regulatory processes. There was also evidence of the dominance hierarchies in the case-study results, with one student guiding the discussion.

Data from the CSILE condition provide a different picture of the students' discourse and of the use of the proforma. In addition to self-regulatory processes, there is significantly more monitoring and regulation of others' ideas and actions. As suggested from the case study, students who were relatively uninvolved in the face-to-face condition found more of a voice in the CSILE condition. The proforma was used to record (and make collaboratively available) individual students' ideas and actions. Students could reflect on the proforma itself, using it to talk *about* ideas rather than as starters for what to say. In the case-study data we saw examples of students coordinating work, dividing up the problem space so that they could take charge of the whole task in more effective ways. While there is a trend that suggests there was more of such activity in the CSILE condition, results are not statistically significant. As suggested in the introduction, this is the most demanding of the metaprocesses that we aimed to support. Participants must think of the task as a whole, construct plans to get more productive contributions from each participant, and then synthesize inputs from all participants. Encouraging more of such activity represents an important challenge for next-generation CSILE designs and for understanding classroom processes that surround its use.

The present research demonstrates powerful regulatory processes in learning, and points to the importance of educational software designs to support such metaprocesses through rich interaction between written and oral discourse, between individual and group processes, and personal and consensual ideation.

Types of regulatory processes employed by students appear highly dependent on the kinds of discourse supports provided. In previous work we have highlighted student theory construction, and students have demonstrated impressive abilities along these lines (Scardamalia et al., 1994). In the present study, discourse of the sort found in scientific research groups was facilitated, and students took on more of the discourse form that typifies experimental research. For example, scientists accept or reject hypotheses depending on whether they are alone or in research groups (Dunbar, 1995). This is similar to the examples above where we saw student A reject the causality of mass on his own. However, under scrutiny in collaboration with B, B pointed out that the way the data were interpreted was incorrect. This led A to reject his initial interpretation and to confirm the hypothesis "mass does matter." It appears that the supports for scientific discourse encouraged cognitive processes similar to those discussed by Dunbar (1995). We need to better understand the distinctive role that technology might play in diverse contexts, and means for enhancing interactions between scientific communities within and beyond school walls.

This study represents what Dunbar (1995) refers to as an "in-vivo" investigation—that is, an inquiry into processes within the classroom culture as opposed to studying them in a laboratory setting. The classroom was a productive environment in which to study the special affordances of oral and written discourse and technology in framing cultures of understanding. However, this situation also had important limitations: a larger and more diverse sample might have yielded more conclusive evidence. An additional limitation is that the data were viewed from only one perspective, that of metaprocesses. It would be possible to adopt other perspectives, with alternate views of the data. Nonetheless, the present framework allowed us to discover effects of direct relevance to collaborative knowledge building.

As suggested in the introduction, innovations in the use of oral and written discourse in learning environments can be thought of as efforts to increase monitoring and reflection. The present study suggests the value of integrating these complementary types of discourse and suggests how computer-based discourse can facilitate this integration in a context of collaborative knowledge inquiry.

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