
DRAFT OF “EPISTEMOLOGY OF INQUIRY AND COMPUTER-SUPPORTED COLLABORATIVE LEARNING”

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ABSTRACT

The purpose of the study was to analyze the epistemological nature of inquiry in computer-supported collaborative learning through comparing three groups of students in Computer-supported Intentional Learning Environments (CSILE). Two of the groups, labeled the Canadian classroom A and B, represented Canadian 10-11-year-old grade 5/6 students. Inquiry in these two groups was compared with corresponding processes in a Finnish grade 4 CSILE class (10-year-old students). Epistemology of the students’ inquiry was examined by qualitatively analyzing the role of question generation, theory formation and peer interaction in the three groups. The results indicated that the Canadian classroom A dealt with scientific information at a very high level of explanation and also engaged in systematic formation of the students’ own intuitive theories. Although the Finnish classroom and Canadian classroom B generated a considerable proportion of explanation-seeking questions, their inquiry focused mainly on factual information. Only the Canadian classroom A engaged in explanation-oriented discourse interaction. It is concluded that the epistemological nature of learning tasks carried out has a very strong influence on the nature of knowledge produced; those in the classroom A characteristically undertook conceptually challenging study projects aimed to facilitate theoretical understanding of the problems being investigated, while those in the Canadian classroom B and Finnish classroom generally sought to gain factual and empirical knowledge that usually did not go beyond everyday phenomena. It is concluded that the Canadian classroom A’s extraordinary epistemological achievements presuppose a very strong engagement of the teacher as well as students’ a commitment to continuously go beyond their earlier pedagogical achievements.

1. INTRODUCTION

The purpose of the present study was to analyze the epistemological nature of elementary school students’ process of knowledge-seeking inquiry in the Computer-
supported Intentional Learning Environments (CSILE) (Scardamalia & Bereiter, 1991). The problem addressed in the study was whether school children’s self-regulated process of inquiry could represent certain fundamental aspects of scientific inquiry, such as engagement with sustained question-driven process of inquiry, explanation-driven process of understanding, collaborative working to improve constructed explanations as well as participation in progressive discourse. The problem was studied by analyzing the epistemological characteristics of knowledge produced by two Canadian and one Finnish CSILE class.

Technical infrastructure for the study was provided by the CSILE environments (Scardamalia & Bereiter, 1989; 1993; 1994; 1996). A central part of the CSILE environment is a communal database for producing, searching, classifying, and linking knowledge. The system facilitates sharing of cognitive achievements by providing each student an access to all textnotes, comments and charts produced by their fellow students. CSILE is designed to foster collaborative learning through its advanced facilities for searching out and commenting on knowledge. Students use CSILE by writing notes, creating charts, and reading and commenting on each other's productions in the context of such domains of knowledge as physics and biology.

CSILE is designed to facilitate elementary school students’ participation in higher-level practices of inquiry characteristic of scientific inquiry. An analogy between the history of science and the development of scientific thinking in childhood as well as between scientific thinking and children’s thinking has been a very important foundation of cognitive research on educational practices. Several philosophers or historians of science (Kitcher, 1988; Nersessian, 1989; 1992; Thagard, 1992) as well as cognitive researchers (e.g., Carey, 1986; Cobb, Wood, & Yackel, 1991; Duschl, Hamilton, & Grandy, 1992; Hawkins & Pea, 1987; Piaget & Garcia, 1989; Scardamalia & Bereiter, 1994) have argued that there is a close relationship between the process of scientific thinking and learning science as well as between the philosophy of science and science education.

Many past efforts to bring scientific inquiry into schools have, however, suffered from promoting an idealistic model of scientific inquiry that does not correspond to actual practices of scientific inquiry (Scardamalia & Bereiter, 1994). Rather that trying to pursue abstract forms of scientific thinking in education, it would be profitable to start with certain practices of working productively with knowledge that characterize scientific inquiry and rely on extended cognitive resources embedded in a community of inquirers. A promising new approach to facilitating scientific thinking in education is based on an idea that scientific inquiry represents a special kind of cultural practice. Several researchers have proposed that in order to facilitate higher-level processes of inquiry in education, cultures of schooling should more closely correspond to cultures of scientific inquiry (Cobb et al., 1991; Hawkins & Pea, 1987).

Scardamalia and Bereiter proposed (1994) that scientific thinking could be facilitated in school by organizing a classroom to function like a scientific research community and guiding students to participate in practices of progressive scientific discourse. They
have argued that there are no compelling reasons why school education should not have the dynamic character of scientific inquiry. The analogy between school learning and scientific inquiry is based on a close connection between processes of learning and discovery. Inquiry pursued for producing new knowledge and inquiry carried out by learners working for understanding new knowledge are based on same kinds of cognitive processes (Scardamalia & Bereiter, 1994; see also Nersessian 1989; 1992). Learning, analogously with scientific discovery and theory formation, is a process of working toward more thorough and complete understanding. Although students are learning already existing knowledge, they may be engaged in the same kind of extended processes of question-driven inquiry as scientists and scholars.

In the present study, the sustained processes of advancing and building of knowledge characteristic of scientific inquiry are called knowledge-seeking inquiry. Several, concurrent, cognitive research projects share a common goal of fostering such research-like processes of inquiry in education (Brown & Campione, 1996; Carey & Smith, 1995; Lampert, 1995; Perkins, Crismond, Simmons, & Unger, 1995; Scardamalia & Bereiter, 1994; Xiadong, Bransford, Hmelo, Kantor, Hickey, Secules, Petrosino, Goldman, & The Cognition and Technology Group at Vanderbilt, 1996). Knowledge-seeking inquiry entails that knowledge is not simply assimilated but constructed through solving problems of understanding. By imitating practices of scientific research communities, children can be guided to participate in extended processes of question- and explanation-driven inquiry.

By synthesizing results of the philosophy of science and cognitive research a framework can be constructed for analyzing essential aspects of progressive knowledge-seeking inquiry that characterize scientific research. The process of knowledge-seeking inquiry starts from an agent’s cognitive or epistemic goals that arise out of his or her dissatisfaction with the state of present knowledge (Hintikka, 1985). Cognitive goals guide and regulate the process of inquiry. Knowledge-seeking inquiry is facilitated by learning that is focused on working toward more coherent and deeper understanding through recognizing weaknesses and limitations of one’s own knowledge (Scardamalia & Bereiter, 1993; 1996).

Recent approaches to the philosophy of science have strongly emphasized the role of problems or questions in scientific inquiry (Laudan, 1977; Hintikka, 1985). From a cognitive point of view, inquiry can be characterized as a question-driven process of understanding. Without a research question there cannot be a genuine process of inquiry although information is frequently produced at school without any guiding questions. A research question activates an agent’s background knowledge by facilitating in-depth search of memory; simultaneously, it facilitates making inferences from one’s knowledge and guides one continuously to relate what he or she already knows to new information (Hintikka, 1982; Macmillan & Garrison, 1988; Sintonen, 1990). From the cognitive viewpoint, particularly important questions arise from problems of understanding and explanation; and, correspondingly, explanation-seeking research questions have a special cognitive value (Bereiter 1992; Scardamalia & Bereiter, 1992).
The question-driven process of inquiry provides heuristic guidance in the search for *new scientific information*. Considerable advancement of inquiry cannot be made without obtaining new information. Further, large bodies of information cannot be managed without questions that guide and constrain the knowledge-seeking process and help to structure information obtained. All scientific information does not have equal cognitive value; explanatory or theoretical knowledge has a key role in conceptual understanding, and, thus, a special status in the cognitive process of inquiry. Further, characteristic of knowledge building activity was taking conflicting information as problematic, something that needs to be explained (Bereiter & Scardamalia, 1993; Chan, Burtis, & Bereiter, 1997).

Another important aspect of inquiry is generation of *one's own explanations, hypotheses or conjectures* (Carey & Smith, 1995; Lampert, 1995; Perkins et al., 1995; Scardamalia & Bereiter, 1989; 1993). In order to foster dynamic change of conceptions and integration of knowledge structures, an agent has to engage in an intentional process of generating his or her own explanations and theories. If the process of inquiry is carried out as a strong, systematic cognitive effort and relevant new information is obtained, the agent often succeeds in creating more and more sophisticated explanations. Knowledge emerges through his or her intentional attempts to explain and understand problems being investigated; it is usually connected with the learner's other knowledge in a rich web of meaning connections.

Several important aspects of knowledge-seeking inquiry characteristic of scientific research outlined above are implemented in the structure of the Computer-supported Intentional Learning Environment, CSILE and corresponding cognitive practices. CSILE is designed to engage students with an extensive process of setting up research questions, generating and improving their own intuitive explanations and searching for scientific information. Participation in all aspects of the process of knowledge-seeking inquiry is facilitated by use of CSILE’s Thinking Types. Further, CSILE fosters socially distributed inquiry by providing tools for sharing of cognitive achievements. CSILE students’ learning community is jointly responsible of their knowledge advancement. The system provides the users with advanced tools for communicating with the other members of the learning community. Thus, it appears that the CSILE environment has a potential to facilitate participation in higher-level practices of inquiry.

The present study focuses on analyzing CSILE students’ practices of knowledge processing. It is important to notice, however, that CSILE provides only a technical infrastructure for knowledge-seeking inquiry; hence it can be used also as a new means towards traditional ends (see Salomon, in press). In order to have significant pedagogical advantages, CSILE use should be intentionally grounded on practices of knowledge-seeking inquiry. It seems that in order to effectively facilitate participation in higher-level practices of inquiry in education and exploit new technology-based learning environments at school, constraints and conditions for successful application of computer-supported collaborative learning should be carefully examined. There are not enough research data, for instance, about how this kind of knowledge-seeking inquiry works in different school
environments and classroom cultures or how teachers with different pedagogical and domain expertise may use the new cognitive resources provided by CSILE and implement the practices of collaborative knowledge-seeking inquiry. Thus, an important aim of the study was to examine how different practices of computer-supported collaborative learning influenced the epistemological nature of the students’ inquiry.

The study focused on examining conditions on which computer-supported collaborative learning facilitates higher-level practices of inquiry by comparing three groups of CSILE students. Epistemology of inquiry was examined through analyzing the role of basic elements of inquiry such as question generation, theory formation and peer interaction, in different classroom cultures, representing both Canadian and Finnish CSILE groups. This kind of cross-cultural comparison of educational processes is, in some respects, problematic; there are often historical and cultural differences that may easily be overlooked. However, in the present case the Canadian and Finnish CSILE students were working with the same technology-based learning environment by carrying out same kinds of study projects. Moreover, the Finnish CSILE experiment was intentionally designed to replicate achievements of the Canadian CSILE groups. As a consequence of working with the same learning environment, both the structure and process of the students’ inquiry were relatively homogeneous. Further, the knowledge processed by the CSILE students was analyzed from an epistemological viewpoint emphasizing the epistemological nature of inquiry more than the concrete contents of problems solved or projects carried out. So there is a reason to presume that the epistemological level of analysis, in the present case, can be abstracted from potentially culture-specific factors. The study was entirely based on a conceptual as well as qualitative and quantitative analysis of students’ written productions from CSILE’s database, and, therefore, it did not give direct information about psychological processes involved in CSILE use.

2. METHOD

2.1 Subjects

The purpose of the study was to examine how practices of knowledge production and peer interaction differed between three groups of CSILE students. These groups did the same sorts things with CSILE, such as project learning, but followed different pedagogical practices. The Canadian study material represented productions of two parallel grade 5 and 6 classes (Canadian classroom A and B) over one year at an inner-city public school in Toronto, Canada. In the school studied, a larger than normal proportion of children came from middle-class and upper middle-class homes. However, the student population was ethnically heterogeneous, and included a number of students from educationally disadvantaged homes (see Scardamalia et. al., 1992). Processes of inquiry in these groups were compared with corresponding processes in a Finnish grade 4 CSILE class (10-year-old students) from the city of Helsinki (see Lipponen & Hakkarainen, 1997 for background of the Finnish experiment). Data regarding the composition of groups that
participated in the study is presented in Table 1. Although assigning the students to these two classes was reported by teachers and principal to be random, gender distribution of the students in the Canadian classrooms was outside of what might be expected with randomized sampling (see Table 1). The relative proportion of female students was larger in the Canadian classroom A than in the classroom B ($\chi^2=7.1$, df=1, p<.008).

<table>
<thead>
<tr>
<th>GROUP</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canadian A</td>
<td>9</td>
<td>19</td>
<td>28</td>
</tr>
<tr>
<td>Canadian B</td>
<td>19</td>
<td>9</td>
<td>28</td>
</tr>
<tr>
<td>Finnish</td>
<td>13</td>
<td>13</td>
<td>26</td>
</tr>
<tr>
<td>TOTAL</td>
<td>41</td>
<td>41</td>
<td>82</td>
</tr>
</tbody>
</table>

There were significant differences between the Canadian and Finnish CSILE groups. The Canadian CSILE students had started their school at age 6, having one year more experience of education than the Finnish group who started their school at age 7. Moreover, the Canadian groups were mixed grade 5/6 classrooms so that 67.9% (n=38) of the 56 students were at grade 6. It is possible that the older students provided a kind of expert model for the younger students in the Canadian groups, and, therefore, affected the general quality of inquiry in the groups. On the other hand, the Finnish students had started to use CSILE at grade three so that they had more experience of working with CSILE (three whole terms) than the Canadian subjects; only 44.6% (n=25) of the Canadian students had used CSILE over a two-year period. Presumably, this difference compensated for the higher age-level of the Canadian students. The groups shared a common structure and process of inquiry and worked with same type of independent study projects. Therefore, the groups can be compared insofar as the differences mentioned above are taken into consideration.

2.2 Study material

The study was based on an analysis of CSILE students’ written productions, posted to CSILE’s database. The material represented data occurring naturally while the students carried out their study projects, working with CSILE. In working with CSILE, the students produced daily, or at least several times a week, computer entries called “notes” in the context of their study projects. The study was carried out by qualitatively and quantitatively analyzing knowledge produced by the students to CSILE’s database.

The Canadian CSILE students conducted many different kinds of projects in biology and physics. In the case of the Canadian classroom A, the analysis concerned three
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different projects, Force, Cosmology, and Electricity, in physics and one project, Human
Biology, in biology. The purpose of the Force project was to explain different forms of
force, especially gravity. In the Cosmology project the students were asked to explain
how the universe changed and how it will be in future. The Electricity project was fo-
cused on explaining what happens inside a wire when electric current passes through it.
The Human Biology project focused on examining biological processes in the human
body, such as how cells or the circulatory system function. The students in the Canadian
classroom B were often working on individual projects, and, therefore, their topics were
more heterogeneous than those of the Canadian classroom A. Biology was the main focus
of the Canadian classroom B, and the most important projects carried out were Geogra-
phical Areas and Protozoa. Further, the classroom conducted Mammoth (lever) project in
physics and Continental Drift project in geology. In addition, the group used CSILE in
working with mathematics, which was not focus of the two other groups; such work was
excluded from the analysis. The Finnish CSILE group used CSILE to carry out study
projects in biology and environmental studies (Northern Countries; Natural Phenomena;
Ecology; Human). Frequencies of CSILE students’ ideas, analyzed qualitatively, are pre-
sented in Table 2. The CSILE students produced hundreds of research questions, notes
presenting their intuitive and scientific knowledge, as well as written comments.

Table 1.
Productions of the Two Canadian and the Finnish CSILE Group Analyzed Qualita-
tively

<table>
<thead>
<tr>
<th>GROUP</th>
<th>Research Questions</th>
<th>Knowledge Ideas</th>
<th>Communicative ideas</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>%</td>
<td>f</td>
<td>%</td>
</tr>
<tr>
<td>Canadian A</td>
<td>983</td>
<td>30.3</td>
<td>1727</td>
<td>53.2</td>
</tr>
<tr>
<td></td>
<td>537</td>
<td>16.5</td>
<td>3247</td>
<td>100.0</td>
</tr>
<tr>
<td>Canadian B</td>
<td>569</td>
<td>31.3</td>
<td>721</td>
<td>39.6</td>
</tr>
<tr>
<td></td>
<td>530</td>
<td>29.1</td>
<td>1820</td>
<td>100.0</td>
</tr>
<tr>
<td>Finnish</td>
<td>150</td>
<td>13.5</td>
<td>341</td>
<td>30.7</td>
</tr>
<tr>
<td></td>
<td>619</td>
<td>55.8</td>
<td>1110</td>
<td>100.0</td>
</tr>
</tbody>
</table>

From Table 1 can be inferred that there were considerable differences in product-
tivity of the Canadian classroom A and B and the Finnish group. It is particularly evident
that the Finnish students did not produce as many research questions as the Canadian stu-
dents.
2.3 Method of data analysis

By relying on conceptual tools provided by the philosophy of science and cognitive theory, methods were developed for analyzing the epistemological nature of the students’ inquiry. CSILE students’ written productions (or “postings” to the database) from CSILE’s database were analyzed through qualitative content analysis (see, for example, Chi, 1997). Coding categories used in the qualitative content analysis were derived from the theoretical review concerning knowledge-seeking inquiry in order to increase validity of the study. The analysis was semantic in nature and focused on the basic categories of CSILE students’ knowledge-seeking inquiry, i.e., research problems, intuitive explanations, scientific information sought by students, and comments.

In order to make a reliable qualitative classification of the material possible, CSILE students’ notes were first partitioned into ideas (regarding segmentation of data for content analysis, see Chi, 1997). An idea as the unit of analysis corresponded to the basic elements of CSILE students’ inquiry, e.g., their research questions, intuitive explanations, pieces of scientific information or explanation sought by them, or comments between the students. The reliability of partitioning was assessed by asking two independent coders to segment 200 notes into ideas. The Pearson correlation between number of ideas identified by the two coders was 93.8.

A basic assumption of the study was that knowledge-seeking inquiry is a question-driven process. The general nature of research questions appeared to determine the epistemic nature of the knowledge-seeking process and what kinds of cognitive operations were available for a student during inquiry. The epistemological nature of the students’ research questions was analyzed by classifying each research question according to whether it was fact- or explanation-seeking in nature. How and why questions are typical explanation-seeking questions and cannot be satisfactorily answered without elaborating an explanation. Further, many what and indirect questions can be transformed into explanation-seeking why or how questions. Who, where, when, how many, and some what questions represented fact-seeking questions that can be answered by providing factual information.

In answering their research questions, CSILE students searched for different kinds of scientific information and generated their own intuitive explanations and theories. Each knowledge idea was classified according to type of knowledge, i.e., whether its main content represented a) new scientific information or b) the student’s own intuitive explanation. “Scientific information” means that a student reviewed or introduced pieces of new scientific facts or theories; i.e., provided information that he or she or the group as a whole was not yet familiar with. “Intuitive explanations” refers to notes in which a student generated his or her own view or an explicit theory about the phenomenon in question.

In order to analyze the epistemological nature of knowledge produced by the CSILE students, mean explanatory level of knowledge was analyzed across students’ pro-
ductions representing their intuitive conceptions and scientific information searched by them. Each knowledge idea constructed by the students to answer their research questions was classified by using a five-step scale starting from (1) separated pieces of facts to (5) explanation:

**Level 1. Isolated facts.** A rating of 1 was assigned to CSILE students’ knowledge ideas representing either simple statements of facts or lists of facts with hardly any connecting linkages that would have provided some coherence or integration. Ideas representing isolated, unconnected facts usually represented answers to corresponding fact-seeking questions.

Some related animals are, Sponges, Venusus Flower basket, Portuges man of war, Sea Anomes, Jelly Fish and Hydra.

**Level 2. Partially organized facts.** A rating of 2 was given to ideas that represented loosely connected pieces of factual information. These ideas can be separated from level 1 ideas because the former represented more organized descriptions about empirical phenomena and certain linkages were provided to connect pieces of facts together. Frequently, however, these ideas were not very coherent or comprehensive; at this level information was still produced in a list-like fashion.

I think that there are many different kinds of cells with totally different functions. I only know the names of some cells, the red blood cell, white blood cells, muscle cells and nerve cells.

**Level 3. Well-organized facts.** A rating of 3 was assigned to ideas in which factual information was introduced in a rather well-organized way. These ideas were used to describe different biological and physical phenomena without, however, connecting the description with deeper causal or explanatory relations. Although it was sometimes possible to reconstruct an explanation-seeking question that would be answered by level 3 ideas, no explicit explanation, however, was actually provided.

The absorptive cell is located around the epithelial cells and small intestines. Its purpose is to eat and/or collect food molecules, salts and water that are in the body. Absorptive cells need to use their entire cell structure to move around.

**Level 4. Partial explanation.** A rating of 4 was assigned to ideas that represented some characteristics of explanation but the content of explanation was rather limited or only partially articulated. Typical for these ideas was an explicit attempt to answer to an explanation-seeking question and produce an explanation. However, certain important aspects of the explanation were left open so that the explanation had apparent weaknesses. For example, while answering a question, “Why do sponges and related animals have three ways of reproducing and other animal forms only have one?”, a student produced the following explanation:

I think that the nerves control themselves and that they send messages to the brain so that the brain can control the body. The nerves are just there to tell the brain what is happening because the brain can't be everywhere at once.
Although the ideas were clearly intended to be explanations, there is an apparent need for further articulation; one or several pieces of explanation remain to be explicated. However, regardless of limitations of the explanatory sketches provided, these productions can be separated from level 3 ideas which clearly did not go beyond introducing factual or descriptive information.

*Level 5. Explanation.* A rating of 5 was assigned to ideas in which a relatively well-elaborated explanation was provided. This rating presupposed neither correctness nor coherence of explanation; it was enough that a student clearly constructed and elaborated his or her own intuitive explanation or introduced a scientific explanation.

I think that cells reproduce because we couldn't live on the two cells that we start out as. Somehow the cells know that they have to reproduce. I think that how they reproduce is the cells start to split and the parts of the cell also start to split and they go to the new cell. It's kind of like there are two cells stacked on top of each other and then the one cell just moves off the other cell and you have two cells. Now you have two cells and both those cells reproduce giving you four cells and so on.

My theory of how the glial cells hold the brain together is that, they might be the bigger cells in the brain, that SH talked about. They might work in twos, one to cradle the neuron cells and the other one to sit on top of it to gently squish it, so it wouldn't move around. The glial cells themselves are stuck to the outer covering of the brain.

CSILE students’ peer interaction was analyzed by examining contents of their written communication mediated by the CSILE network. Communicative ideas appeared to reflected how the students themselves conceptualized their knowledge-seeking inquiry.

CSILE students’ comments were classified according to type of communicative idea, i.e., whether an idea 1) supported the note commented expressing agreement, 2) represented neutral exchange of ideas or 3) was critical in nature expressing disagreement. Neutral communicative ideas were further divided into two subgroup according to function of the neutral communicative idea; communicative ideas in which a student requested information/explanation or asked a question, and communicative ideas which he or she provided information/explanation or answered a question.

The object of cognitive activity determines to a great extent the psychological nature of inquiry. Communicative ideas within a comment were analyzed by specifying, in each case, the object of inquiry: i.e., whether the communicative idea was about 1) linguistic form (e.g., spelling mistakes), 2) student-generated research questions being pursued, 3) methods of inquiry, 4) quantity or quality of information sought by the students, 5) intuitive explanations generated by the students or scientific information sought by them, 6) other (e.g., technical aspects of CSILE use), or 6) unspecified. Each communicative idea was considered to represent only one of the above mentioned categories. CSILE students’ peer interaction was analyzed by distinguishing inquiry-related comments from comments that were unspecific or focused on linguistic form, or technical aspects of CSILE use. Further, the proportion of explanation-related communicative ideas was used to assess the epistemological nature of CSILE students’ peer interaction. Explanation-related comments were either those designed to assess explanation constructed
by the student being commented upon or to provide an explanation generated by the student him- or herself. An explicit reference to explanation was not, however, a necessary prerequisite for categorizing a comment as explanation-related; also comments that referred to how hard or easy it is to understand to ideas presented in the note commented upon were regarded as explanation-related.

The investigators analyzed how CSILE students explicated referential relations of their communicative ideas. The analysis was carried out by using a three-step scale for assessing explication of referential relations was analyzed by classifying CSILE students’ comments as explicated, partially explicated and unexplicated. Some of the unexplicated ideas were completely unspecified; in these cases, the main object of the comment could not be specified at all, i.e., one could not determine whether a communicative idea was focused on linguistic form or some aspect of the process of inquiry. Typically, in this kind of comment, reasons for disagreement or agreement were left completely open: "I like your note", "Your note is not good." An explicated comment was self-explanatory, i.e., understandable without any background or contextual knowledge.

To analyze the reliability of the classification, two independent coders classified 200 research questions, 200 knowledge ideas, and 300 communicative ideas representing both the Canadian classroom A and B. The reliability of classifying the Finnish data was assessed in a corresponding way by using two independent raters. Inter-coder reliabilities of the classification were satisfactory and exceeded .70 across practically all variables. Disagreements were discussed after the reliability analysis, and those ideas that were classified differently by the two coders were analyzed again and coded according to a mutual agreement.

Because the classification of CSILE students’ productions was made at the level of ideas, several observations were obtained for each student. On average, the students produced 74 ($SD = 53$) ideas during the period analyzed. In order to identify the most important differences between the groups of CSILE users, the relative importance of different contents in individual students’ comments and notes were studied as proportions, i.e., by analyzing the proportion of certain kinds of content among a student's productions representing the reference category in question.

2.5 An analysis of teacher guidance

Further, we analyzed how teachers of the three groups guided their students’ inquiry by examining comments posted by them to CSILE’s database. The analysis focused on examining teachers' participation in CSILE discourse and whether their comments facilitated deepening inquiry. Data directly concerning teacher practice were not gathered.
3. RESULTS

3.1 Practices of knowledge production

CSILE students’ knowledge production was examined by analyzing the nature of research questions produced as well as the explanatory level of the scientific and intuitive knowledge processed. A direct discriminant analysis was performed using three variables representing the nature of CSILE students’ knowledge production as predictors of membership in a CSILE group. The predictors were mean proportion of student-generated explanation-seeking research questions, mean explanatory level of intuitive knowledge, mean explanatory level of scientific information and CSILE group (Canadian A, Canadian B, Finnish) was used as a grouping variable.

Two discriminant functions were calculated, with a combined $\chi^2(6) = 161.9$, $p<.000$. After removal of the first function, there was still strong association between groups and predictors, $\chi^2(3) = 22.1$, $p<.000$. The two discriminant functions accounted for 93.8% and 6.2%, respectively, of the between-group variability. As shown in Figure 1, the first discriminant function maximally separates the Canadian classroom A from the Finnish classroom and Canadian classroom B. The second discriminant function partially discriminates the Canadian classroom B and Finnish classroom from each other.
Figure 1.
Plots of three group centroids on two discriminant functions derived from three knowledge-production variables (proportion of explanation-seeking research questions, mean explanatory level of scientific information, and mean explanatory level of intuitive knowledge)

The loading matrix of correlations between predictors and discriminant function, as seen in Figure 1, suggested that the best predictors for distinguishing between the Canadian classroom A and the two other groups (first function) were mean explanatory level of scientific knowledge and mean explanatory level of intuitive knowledge. The level of scientific information searched by the Canadian A classroom (mean = 4.15) was a higher than that of the Finnish classroom (mean = 2.18) or the Canadian classroom B (mean = 2.35). Further, also the mean level of intuitive knowledge was higher in the Canadian classroom A’s productions (mean = 4.14) than in those of the Finnish classroom (mean = 2.16) or the Canadian classroom B (mean = 3.35).

Table 3.
Results of Discriminant Function Analysis of Knowledge-Production Variables

<table>
<thead>
<tr>
<th>Predictor variable</th>
<th>Correlations with the discriminant function</th>
<th>1</th>
<th>2</th>
<th>Univariate F (2,79)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean proportion of explanation-seeking questions</td>
<td>.22</td>
<td>.68</td>
<td></td>
<td>15.8</td>
</tr>
<tr>
<td>Mean explanatory level of intuitive knowledge</td>
<td>.61</td>
<td>-.64</td>
<td></td>
<td>77.7</td>
</tr>
<tr>
<td>Mean explanatory level of scientific knowledge</td>
<td>.83</td>
<td>.50</td>
<td></td>
<td>137.9</td>
</tr>
<tr>
<td>Canonical R</td>
<td>.91</td>
<td>.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eigenvalue</td>
<td>5.00</td>
<td>.33</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Two predictors, the proportion of explanation-seeking research questions and mean explanatory level of intuitive knowledge had a loading in excess of .50 on the second discriminant function, which separates the Finnish classroom from the Canadian classroom B. The Finnish classroom (mean = .69) produced a higher proportion of explanation-seeking research question than the Canadian 2 classroom (mean = .53). Simultaneously, however, the mean explanatory level of intuitive knowledge was lower in the Finnish classroom (mean = 2.61) than in the Canadian classroom B (mean = 3.32).
An examination of the pooled within-group correlations among the three predictors revealed that one of the three correlations would show statistical significance at alpha = .05 level if tested individually. There is a positive relationship between mean level of scientific explanation and proportion of explanation-seeking research questions $r(82)=.34$, $p<.05$, indicating that a higher proportion of explanation-seeking research questions was associated with a high mean explanatory level of scientific information.

With the discriminant classification procedure for the total usable sample of 82 students, 84% were classified correctly, compared to 27 (33%) that would be correctly classified by chance alone. The 84% classification rate was achieved by using sample proportions as prior probabilities. The likelihood of correctly classifying the Canadian classroom A students (100%, 28) was higher than that of classifying the Finnish (77%, 20) or Canadian classroom B (75%, 21) students indicating that practices of inquiry were more heterogeneous in the latter groups.

The analysis revealed that the epistemological nature of knowledge production differed substantially between the groups. An explanation-oriented process of inquiry had a prominent role in the Canadian classroom A’s practices of knowledge processing. The Canadian classroom A differed clearly from the two other groups in terms of higher proportion of explanation-seeking research questions and the mean explanatory level of scientific information and mean explanatory level of intuitive knowledge. It was also noticeable that the Canadian classroom A represented very homogeneous practices of knowledge productions; practically all students were carrying out the same kinds of practices of explanation-oriented inquiry. Canadian classroom B’s and Finnish classroom’s inquiry, in contrast, focused on processing factual knowledge and making empirical generalizations. Even if the students of Finnish classroom produced a relatively high proportion of explanation-seeking research questions exceeding in this sense the Canadian classroom B, it was not correspondingly engaged with construction of its own explanations or search for explanatory scientific information.

The present results, however, should be taken with caution because an examination concerning homogeneity of variance-covariance matrices revealed a significant divergence from the assumptions of multivariate analysis (Box’s $M=109.9$, $p<.000$). The varying within-group variances seemed, however, to represent an important aspect of the phenomenon studied. Variance, for example, concerning the mean proportion of explanation-seeking research questions was lower in the Canadian classroom A than in the two other groups because practically all students engaged in producing of this kind of questions. Thus, unequal variances represented an important educational achievement instead of being just a statistical problem (compare Howell, 1987, p.181). Taking the robustness of statistical methods used as well as effect sizes of the phenomena measured into consideration, the results may be considered as providing a relatively accurate description of differences between the CSILE groups.
3.2 Practices of peer interaction

A direct discriminant analysis was performed using four variables representing nature of CSILE students’ peer interaction as predictors of membership in a CSILE group. The predictors were mean proportion of explanation-related comments, mean proportion of critical comments, mean level of explication, and mean proportion of inquiry-related comments. The grouping variable was CSILE group (Canadian A, Canadian B, Finnish). Of the original 82 cases, 1 case representing the Canadian classroom A was dropped from analysis because of missing data, i.e., no comments produced.

Two discriminant functions were calculated, with a combined $\chi^2(8) = 126.6, p<.000)$. After removal of the first function, there was still strong association between groups and predictors, $\chi^2(3) = 50.3, p<.000$. The third discriminant function, however, was not significant. The two discriminant functions accounted for 64.7% and 35.3%, respectively, of the between-group variability. As shown in Figure 2, the first discriminant function separates the Canadian classroom A from Canadian classroom B and Finnish classroom. The second discriminant function discriminates the Finnish group from the Canadian classroom B.

The loading matrix of correlations between predictors and discriminant function, as seen in Table 4, suggested that the best predictors for distinguishing between Canadian classroom A and Finnish classroom (first function) were mean proportion of explanation-related comments and mean level of explication. The students of Canadian classroom A (mean = .49) produced a higher mean proportion of explanation-related comments than the Canadian classroom B (mean = .07) or Finnish (mean = .18) students. Further, a higher mean level of explication of referential relations characterized the Canadian classroom A’s (mean = 2.78) inquiry than the Finnish classroom (mean = 2.21) or the Canadian classroom B (mean = 2.16).
Figure 2.
Plots of three group centroids on two discriminant functions derived from four communicational variables: mean level explication and respective proportions for explanation-related comments, critical comments, and inquiry-related comments

As seen in Table 4, two predictors, mean proportion of inquiry-related comments and proportion of critical comments, had a significant loading on the second discriminant function, which separates the Canadian classroom B from the Finnish classroom. A significantly higher proportion of classroom B students’ (mean = .80) comments were inquiry-related than those of the Finnish students (mean = .38). Further, proportion of critical comments was higher in the Canadian classroom B (mean = .30) than in the Finnish classroom (mean = .10).

Table 4.
Results of Discriminant Function Analysis of Peer-interaction Variables

<table>
<thead>
<tr>
<th>Predictor variable</th>
<th>Correlations with the discriminant function</th>
<th>1</th>
<th>2</th>
<th>Univariate F ( (2,79) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean proportion of explanation-related comments</td>
<td>.70</td>
<td>-.34</td>
<td></td>
<td>36.7</td>
</tr>
<tr>
<td>Mean proportion of critical comments</td>
<td>.43</td>
<td>.48</td>
<td></td>
<td>20.4</td>
</tr>
<tr>
<td>Mean level of explication</td>
<td>.74</td>
<td>-.14</td>
<td></td>
<td>36.8</td>
</tr>
<tr>
<td>Mean proportion of inquiry-related comments</td>
<td>.54</td>
<td>.71</td>
<td></td>
<td>38.0</td>
</tr>
<tr>
<td>Canonical R</td>
<td>.79</td>
<td>.69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eigenvalue</td>
<td>1.68</td>
<td>.91</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
An examination of the pooled within-group correlations among the four predictors indicated that two of the four correlations would show statistical significance at alpha = .05 level if tested individually. There was a positive relationship between mean proportion of explicated comments and proportion of inquiry-related comments \((r(82) = .42, p<.05)\) indicating that inquiry-related comments are more likely to be explicated than other kinds of comments. Further, higher mean proportion of explanation-related comments appeared to be associated with a higher mean proportion of explicated comments \((r(82) = .24, p<.05)\).

With the discriminant classification procedure for the total usable sample of 82 students, 89% were classified correctly, compared to 27 (33%) that would be correctly classified by chance alone. The 89% classification rate was achieved by using sample proportions as prior probabilities. The likelihood of correctly classifying the Canadian classroom A students (93%, 26) correctly was higher than that of classifying the Finnish (89%, 23) or the Canadian classroom B (86%, 24) students.

Results of the analysis indicated that only the Canadian classroom A engaged systematically in explanation-oriented discourse interaction; in the other two groups the proportion of explanation-related comments was significantly lower. Further, explanation-oriented discourse was closely associated in a higher mean level of explicated comments suggesting that the explanation-related comments tend to be more explicated than other kinds of comments. Further, the proportion of inquiry-related comments was lower in the context of the Finnish group than the two Canadian groups. The Finnish students were frequently discussing linguistic form and technical aspects of CSILE use (such as use of Thinking Types and signing of one’s notes). It was also characteristic of the Finnish group to engage in a rather neutral discussion, and produce relatively few supportive or critical comments; this appeared to represent their question-answer discourse (see Hakkarainen, Järvelä, Lipponen, & Lehtinen, 1998). Critical comments were frequently produced by the Canadian classroom A in which a very constructive culture of communication dominated. The present results, however, should be taken with caution because an examination concerning homogeneity of variance-covariance matrices revealed a significant divergence from the assumptions of multivariate analysis (Box’s M = 60.1, \(p<.000\)). The varying within-group variances seemed, however, to represent an important aspect of the phenomenon studied.

3.3 Teacher guidance

3.3 Teacher guidance

The analysis of teachers’ participation in CSILE discourse revealed that although the Finnish CSILE teacher produced only one comment, the teacher of Canadian class-
room A produced 24 and classroom B’s teacher 32 comments. Thus, it appears that the Finnish teacher left his students to work alone in CSILE, and, perhaps did not even read the students' productions. Teacher B, in contrast, participated actively in CSILE discussion. However, his comments were produced in the context of one project, Continental Drift. Across all projects, Teacher A was equally active and commented on students' productions.

An examination of the contents of the teachers' comments indicated that 75% (24 out of 32) of comments of teacher B were supportive in nature ("this is very reasonable answer to this question"; "your answer makes good sense"), yet the reasons for support were not usually specified so that his remarks provided only general encouragement for the students. Further, only 21% (5 out of 24) of teacher A’s comments were supportive in nature ("this is interesting"; "this is a good problem"). This finding reflected the general nature of classroom A's discourse in which students very constructively pursued their inquiry; members of this learning community apparently did need to emphasize their mutual support in their discourse interaction. The comment produced by the Finnish teacher was also supportive ("your note is good but the arrow representing wind is in a wrong place").

Both teacher A and B requested students to do some more research through their comments. However, teacher A's focus appeared to be on students' understanding whereas teacher B focused more on factual knowledge. 88% (21 out 24) of teacher A’s comments were explicitly focused on requesting students to explain or clarify their theories with comments like "Why do you think this is so?" or "Could you explain it?"

Teacher A appeared to guide the students indirectly {{??; sounds pretty direct to me}} to deepen their inquiry; he did not give the students information about subject matter but pushed the students themselves to further articulate their theories. The following are typical examples of teacher A’s comments.

I think this is a very interesting note. I was wondering if you were going to consider how the cells differ in function? For example, do they have any special structures that enable them to communicate with other cells? (teacher A)

In your NI [New Information] you wrote that the only nerve cells you get are the ones that you are born with. Does this mean that your brain is its maximum size at birth? Also, how would your nerve cells service the increased volume of your body as you grow? (teacher A)

C: You raise some interesting points in this note. I wonder what antigenic proteins are? Could you explain that? What do you suppose the relationship is between antigens and antibodies? (teacher A).

Teacher B's comments, in contrast, were only seldom explicitly focused on explanation. Only 22% (7 out of 32) of his posted comments contained an explicit request of explanation. Instead, he asked students to "give some examples", "add more details" or to provide a more exact description of the phenomenon being investigated. Presumably, he tried to guide students towards specification of their own conceptions or towards a right answer.
I think that your idea is a good one. I would suggest that you go back to the note and make sure that it makes sense. You need to write down exactly what you think happened. In other words; do some more thinking and add details (teacher B).

This is a good beginning comment on the continents but you could give some details as to exactly how the continents are attached. A drawing on Kid Pix attached to your hypothesis would help (teacher B).

This is a very logical answer. Perhaps you could be more specific and say or show [Kid-Pix] exactly where you think Hawaii might have fit into North America. Here is another clue: Find out what kind of soil Hawaii has (teacher B).

Your answer makes good sense. Perhaps you could do some research and try to find out if what you think is true (teacher B).

Teacher B’s guidance appeared to be more direct than teacher A’s guidance. Teacher A’s comments were frequently questions whereas teacher B’s comments were statements. However, teacher B’s comments did not appear to affect the depth of students inquiry whereas teacher A’s requests of explanation led, in many cases, to significant deepening of inquiry.

To conclude, there were substantial differences between the Finnish and Canadian teachers in terms of intensity of commenting; the Canadian teachers participated in CSILE discourse much more actively than did the Finnish teacher. Further, teacher A’s comments were focused on facilitating elaboration of the students’ own theories and explanations whereas teacher B guided the students to work to obtain a more detailed and exact account of the problem being investigated. Also, teacher A’s style of guidance seemed to be more indirect in nature than that of teacher B.

4. DISCUSSION

The analysis indicated that there were substantial differences concerning the epistemological nature of inquiry between three groups of CSILE students. Although the Canadian classroom A engaged with explanation-oriented process of inquiry, the Finnish classroom and Canadian classroom B dealt with factual and descriptive information. In evaluating the results, one should take into consideration that the groups differed from each other in several ways, so that it is not possible to determine a single factor that would explain differences between the groups. Nevertheless, the analysis revealed that there were striking similarities between the present Canadian classroom B and the Finnish classroom in spite of different cultural backgrounds and educational contexts. Moreover, practices of knowledge production of these two groups diverged more from the Canadian classroom A than from each other. Such findings are to be taken as suggestive, however, further rigorously designed research is necessary to more definitively identify variables implicated in the three groups’ performances.
The study indicates that an important explanation for the differences between the CSILE groups may be found in the implicit epistemological assumptions and cognitive design of CSILE projects conducted in the three classrooms. Typical of the Finnish classroom and Canadian classroom B was to carry out conceptually unchallenging study projects that focused on the familiar everyday environment. The design of study projects carried out by the groups guided the students in working with factual knowledge rather than searching for explanatory scientific knowledge. Although the Finnish group and Canadian classroom B produced explanation-seeking research questions, the scientific information processed by the groups was at a substantially lower explanatory level than that of the Canadian classroom A. The projects of the groups focused mostly on observable empirical phenomena such as selecting an interesting phenomenon (e.g., species, countries, places) and searching for basic information about it. The most challenging task carried out by the Canadian classroom B or Finnish group seemed to be to examine differences and similarities between phenomena being investigated. The similarity-based approach (cf. Murphy & Medin, 1985; Keil, 1989), adopted by the Finnish and Canadian classroom B, seemed to lead to generation of list-type solutions instead of elaboration, articulation, or integration of knowledge.

Although the projects of the Canadian classroom B or Finnish groups would have provided a good opportunity to learn to conceptualize biological taxonomies in a principled way (e.g., warm-blooded versus cold-blooded animals), these taxonomies were frequently used as labels, and none of the students used group membership as a tool for inference (cf. Thagard, 1990). Further, the students working in the Finnish or Canadian classroom B did not come to discover deep biological principles, such as reproductive success (see Brown & Campione, 1996), in explaining the adaptation of the species studied. Although the projects carried out by the groups would have provided a good opportunity to acquire conceptual understanding of deep biological or physical principles (see Brown & Campione, 1996), the students were frequently bound to surface-level phenomena. The epistemological nature of the Canadian classroom A’s projects was different from that of the two other groups. It was characteristic of the Canadian classroom A to conduct conceptually challenging study projects that focused on gaining theoretical understanding of the problems being investigated.

Further, common to the Canadian classroom B and Finnish classroom was that the students’ own intuitive theories were not systematically facilitated. In many cases, students were explicitly guided simply to describe experimental procedures used and to form their own qualitative observations but not encouraged to construct their own hypothesis, conjectures or theories. Lampert (1995) pointed out that engaging students in a genuine process of inquiry is a very challenging task, requiring much effort from teachers. It requires building a new culture of learning where such generation of students’ own theories has a legitimate role. A necessary prerequisite for emergence of constructive, scientific-style of inquiry appears to be a culture in which each student is encouraged to articulate his or her intuitive theories, and in which each theory is respected as well as critically evaluated. This kind of culture, of which the Canadian classroom A provided an excellent example, allows each student to participate in articulating of explanations without being
afraid of unavoidable mistakes. The present analysis of the Canadian classroom A’s process of inquiry has revealed that they were ready to take the challenge. White and Gunstone's (1989) analysis has shown how difficult this kind of changes may be to achieve.

Results of the present study indicate, further, that there is a very close relationship between the epistemological nature of knowledge produced by an individual student and the learning tasks carried out. Classroom culture and the nature of learning tasks appear to create an economy of inquiry that significantly constrains each student’s practices of inquiry. It would have required considerable mental effort from students in the Canadian classroom B and Finnish classroom to transform the given learning tasks into more challenging ones and to go deeper into the topic when the learning tasks in question did not require in-depth conceptual understanding. The nature of knowledge produced was empirical across all students, and this seemed to reflect the nature of the learning tasks carried out rather than individual cognitive achievements. This contention was supported by the fact that differences between the collaborative and the two other groups were far more substantial than within-group differences between low- and high-achieving students. It appears that elementary school students do not break the constraints of concurrent pedagogical practices or the boundaries of empiricist epistemology without the teachers’ cognitive and epistemological guidance (Lipponen & Hakkarainen, 1997; Järvelä et al., 1997). Without a teacher’s guidance or examples of advanced models of cognitive practices, all students, regardless of their individual cognitive competencies, might well remain at a more elementary level in their inquiry as observed in the case of the Canadian classroom B and Finnish group.

Examination of the material indicated that the Canadian classroom A’s extraordinary epistemic achievements presupposed a very strong engagement of the teacher; the conceptually challenging study projects could not have been carried out without the teacher’s guidance and active participation in CSILE discourse. The teacher of the Canadian classroom A apparently gave the students a great deal of epistemological support by providing an expert model of higher-level processes of inquiry. Like a facilitator in a problem-based learning, the teacher consistently communicated with the students at a metacognitive level by requesting explication of explanatory relations; he guided the students in monitoring the progress of their understanding without directly giving them information (cf. Savery & Duffy, 1996). This orientation turned out to be very effective; the students were often able to detect their misunderstandings, revise their theories correspondingly and refocus their inquiry on the basis of the teacher's and the other students’ requests for explication. With minimal instructional intervention, the teacher was able to guide the students to ask relevant questions, create ingenious intuitive theories and find explanatory scientific information.

The teacher of the Finnish group did not participate in the students' process of inquiry as actively as the teachers of the two Canadian groups. He provided certain preliminary questions for the students to answer, but did not systematically comment on the students' productions. Yet without actively engaging in a CSILE-type discourse the teacher can neither help the students to advance in their process of inquiry, nor to recognize sig-
significant contributions, nor to generalize emerging progressive practices of inquiry. In order to successfully elicit higher-level practices of inquiry, the teacher should not let the students alone, but provide an expert model by his or her own example. The Canadian classroom A, by contrast, appeared to represent a second-order environment in which the teacher and students continuously went beyond their earlier achievements (cf. Bereiter & Scardamalia, 1993).

However, systematic observational or other kinds of process-sensitive data concerning CSILE teachers' classroom practices were not available. Apparently, the significance of teacher contribution has not been sufficiently emphasized in CSCL research, and, therefore, researchers have entirely focused on examining students' activities. In the case of the present study, the significance of teacher guidance became salient to the researchers only after finishing the data collection. The present data do not establish in what manner teacher practices are linked to desired collaborative outcomes, hence further research is needed to answer questions about the specific causal and facilitative roles of such practice. The results of the present study, however, do indicate that it is crucial to carefully document how successful CSCL teachers function in their classroom in order to be able to promote successful higher-level practices of inquiry through CSCL.

In assessing the Canadian classroom B’s and Finnish classroom’s epistemic achievements, it must be emphasized that the present study analyzed the epistemology of inquiry rather than the commonly constructed “educational value” of activities the students undertook. Yet there is no doubt that participation in CSILE activities, such as more intensive writing and peer interaction, was educationally valuable in all of the CSILE groups. Comparisons of school achievements between the CSILE classes and normal classes has revealed that both of the groups achieved better results than students working in conventional classrooms (Scardamalia et al., 1992). One may distinguish between first-order and second-order effects of educational technology. The first-order effects refers to learning of skills of using information technology, developing skills of knowledge acquisition, increased motivation, and using extended sources of information. It is also likely to involve changed structures of classroom activities and changed division of cognitive labor between the teacher and the students; students engaged in the CSCL are not doing same kinds of things anymore but are involving themselves in many different kinds of independent research projects. These first-order effects appear to be a normal consequence of engagement with computer-supported collaborative learning but do not, as such, break the boundaries of traditional empiricist educational epistemology. The second-order effects involve engaging students in a sustained question- and explanation-driven inquiry and progressive discourse analogous to scientific practice. It means a profound change in the students’ conceptions of what learning and knowledge are all about. This kind of epistemological shift cannot be achieved without strong pedagogical support from the teacher.

To summarize, results of the present study indicate that students need a great deal of pedagogical and epistemological guidance in order to participate in higher-level processes of inquiry analogous to scientific inquiry. The students cannot be expected to dis-
cover these practices by themselves without guidance and expert modeling. A special effort should be made to provide epistemological guidance to the students; i.e., to make them aware of the cognitive value of different kinds of questions, advantages of forming one’s own intuitive theories as well as to help them to recognize the valuable kinds of explanatory scientific knowledge. However, implementation of higher-level practices of inquiry at school is constrained by the fact that teachers themselves have seldom had personal experience or become acquainted with the epistemology of scientific inquiry. These considerations suggest that more resources should be invested in teacher education, in giving pre-service teachers personal experience as well as conceptual understanding of advanced processes of knowledge-seeking inquiry. Pre-service teachers could be guided to participate in analyzing school children’s processes of inquiry mediated by CSILE or some other piece of groupware in collaboration with researchers. The same methods could be used to facilitate practicing teachers’ professional development.

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