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Text-Based and Knowledge-Based Questioning by Children

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Three studies investigated the ability of elementary school children to ask and recognize educationally productive questions. Knowledge-based questions formulated in advance of instruction were found to be of a higher order than text-based questions produced after exposure to text materials. Depending on familiarity of the topic, knowledge-based questions varied between basic questions asking for information needed for orientation to a topic and "wonderment' questions often aimed at explanation or at resolving discrepancies in knowledge. Children's questions are seen as a potentially valuable resource in education but one that requires a different kind of classroom community from the several kinds commonly found. The potential of a computer-based medium, computer-supported intentional learning environments, for supporting a knowledge-building community is briefly considered.

Although educators of all persuasions would probably agree that it is a good thing to encourage students to ask questions, there is great variation in the role assigned to students' questions by different educational approaches. At one extreme is programmed instruction, in which all the questions come from the program, and students' questions are at best peripheral. At the other extreme are child-centered approaches in which students' questions are a major directive force.

There are reasons for doubt about how large a role students' questions should play. Miyake and Norman (1979) argued that it takes considerable domain-specific knowledge to ask good questions. Students, therefore, might be in a poor position to ask educationally productive questions-especially at the beginning of their study of a topic, which is the point at which questions could have the most directive effect.
The present studies attempt to address the question of the educational potential of students' questions. The basic data are student-generated questions on various topics and ratings of those questions by adults, teachers, or students themselves. These studies do not test actual effects of incorporating students' questions into the curriculum. What part students' questions should play in education and how that part should be arranged are instructional design issues whose resolution depends on the educational potential inherent in the questions themselves. That potential and the conditions that affect it are the concern of the present studies.

Reviewing North American research on self-questioning, Wong (1985) found that most of this research grew out of the prose-learning tradition and involved students asking questions as part of their study of a text. We refer to such questioning as *text based*.

Questions are prompted by a text and are generally about the text. They may range from high-level critical or analytical questions, down through questions about the meanings of unfamiliar words, to questions that are merely grammatical transformations of text statements (Bereiter & Scardamalia, 1989).

A different orientation to the educational role of questions may be seen in the English infant school tradition (Central Advisory Council for Education, 1967) and its contemporary manifestations in open education. Starting with the work of Susan Isaacs (1930), the "child's own question" has been seen as a prized object that should be at the center of the curriculum. What makes a question the child's own is that it springs from a deep interest of the child or arises from an effort to make sense of the world. We shall refer to this kind of questioning as *knowledge based*. The source of questions is a gap or discrepancy in the child's knowledge or a desire to extend knowledge in some direction.

We do not intend to show a sharp distinction between text-based and knowledge-based questioning. Knowledge-based questions often are stimulated by events, and reading a text can e such an event. The distinction between text-based and knowledge-based questioning is, in fact, closely related to the two kinds of mental representations that, according to van Dijk and Kintsch (1983; Kintsch, 1988), are formed during text comprehension-a text base, representing the propositional content of the text, and a situation model, representing the world as it relates to the text. Clearly, questions may arise with respect to either representation, but they would not be the same questions. Although, as indicated, different educational traditions have led to differential interest in the two kinds of questioning, there is a common underlying conception of the student as an active agent in learning.

The value of distinguishing between text-based and knowledge-based questioning, as we intend to show, is empirical. The two kinds of questioning tend to produce qualitatively distinct kinds of questions, and these different kinds of questions imply differences in the extent to which students can drive and direct the learning process.

Although it is commonplace to distinguish between bookish classroom questions and the more normal kinds of questions arising from a desire to know the answer, there has been relatively little research comparing these kinds of questions and how they figure into educational discourse. Instead, research on questioning in classrooms has branched off into separate paradigms-with researchers interested in text-based questioning adopting the process-product paradigm and those interested in knowledge-based questioning adopting a sociolinguistic approach (Carlsen, 1991).

Empirical comparison of text-based and knowledge-based questioning is highly problematic. We call attention to the problems-in order to explain why the present studies were carried out in an atypical situation, using methods that are less straightforward than the issue might seem to require. The central problem is that text-based and knowledge-based questions presumably arise from different psychological sources, and so the optimal conditions for observing one may be inappropriate for observing the other. Text-based questions are typically produced on demand. Students are specifically instructed to

generate questions in response to certain cues. Knowledge-based questions, by contrast, are presumed to occur spontaneously and, therefore, must be picked up by nonintrusive observation. Comparisons of quantity, quality, content, and the like are therefore vitiated by a confounding of question types with data sources.

Gamoran and Nystrand (in press) investigated what they called "test questions" and "authentic questions" by observing the questions that occurred during ordinary classroom discourse. This approach required some after-the fact way of categorizing the questions. Gamoran and Nystrand chose the distinguish text questions from authentic questions according to whether they did or did not have prespecified answers. The difficulty of applying such a criterion is illustrated by the following question, which appeared in classroom protocols we examined: Were the Middle Ages before or after Socrates?

The question clearly has a single right answer and might have been asked to test someone. In context, however, it appeared that the student who asked the question was genuinely concerned with getting the Middle Ages situated chronologically in relation to the few other remote historical markers with which he was already familiar. Thus, we want to call it a knowledge-based question, and we trust Gamoran and Nystrand would want to call it authentic, but the judgment clearly depends on the speculative interpretation of a whole situation and not simply on the question itself. This seems to be an unavoidable difficulty with studying questioning through classroom observation.

A further difficulty with classroom observation is that, under ordinary school circumstances, it may be difficult to obtain a significant number of knowledge-based questions from students. Susskind (1969) observed only about two student-generated questions per hour in classroom discourse-a rate that is two orders of magnitude less than that observed in young children at home (Tizard & Highes, 1984). If text-based questions are the only kind the students are accustomed to at school, that may be the only kind produced, regardless of procedure.

To obtain comparable samples of text-based and knowledge-based questions, we studied elementary school students with at least 6 months of experience in an environment in which they regularly generated written questions related to topics of study and in which these questions were used to direct their study. The environment was that of elementary school classrooms where we have been working closely with teachers and students in the development of computer-supported intentional learning environments (CSILE), a networked system organized around a student-generated database to which students contribute text and graphical notes in all subject areas as well as comments on one another's notes (Scardamalia, Bereiter, McLean, Swallow, & Woodruff, 1989). It is a common practice in the CSILE classroom for students to generate their own questions at the beginning of a unit of study. Typically, these questions are produced after some introductory lessons, videotapes, or browsing of reference material, and the questions are intended to serve as goals for further study. That is, students are expected to go out and seek answers to the questions, entering their findings into the community database.

Along with these regular classroom activities involving CSILE, students have also taken part in a variety of informal sessions in which we explored possible new curricula or strategies for later implementation in CSILE. In these informal sessions, children were encouraged to ask questions in a context of free speculation, without prior study and with no suggestion that they would be held accountable for answering them. The questions produced in these sessions seemed to be qualitatively different from the questions produced when studying regular units. When producing questions as part of work on a unit, students seemed to produce text-based questions- questions to which the answers could be found in the material to which they had already been exposed. When students generated questions without prior study, the questions seemed to be of a more knowledge-based kind. Students asked about things they seemed genuinely to wonder about.

The present studies grew out of these informal observations. We contrast questions generated by students in the course of preparing to work on assigned unites of study (the text-based condition) with questions generated by students who were asked, in advance of any study of the topic, to write down things they wondered about (the knowledge-based condition). Thus, instead of trying to classify questions themselves as text based or knowledge based (which entails the difficulties of elicitation and observation discussed earlier), we distinguished between two conditions of question generation that are hypothesized to result in qualitatively different questions and then examined for such differences.

The first question, of course, is whether questions produced under the two conditions actually are different. That question was investigated in Study 1. Several differences were found that point to greater educational potential for questions produced under the knowledge-based condition. A second question, prompted by the work of Miyake and Norman (1979), is whether asking educationally valuable knowledge-based questions requires substantial prior knowledge. Study 2 parallels Study 1, except that the topic for question asking was one of which the students indicated little prior knowledge. This topic elicited different kinds of knowledge-based questions but ones that indicated appropriate adaptations to the students' perceived level of knowledge. In Studies 1 and 2, judgments of the educational value of individual questions were made by adults. Study 3 was concerned with how well students themselves can make such educational judgments-an important consideration in determining how students' questions should be used in a curriculum.

The design of the studies was constrained by what the students happened to be studying during the term of the research. This was necessary so that the text-based condition could be one in which students recognized that they would be accountable for seeking answers to the questions they asked. This gained a measure of ecological validity, but at the price of a certain amount of patchwork in design, because plans had to be altered in the face to day-to-day contingencies. The result is that there are alternative explanations of various results that cannot be ruled out but which might have been tested by more completely controlled designs. We attempt to note these alternatives in the Discussion sections.

STUDY 1: QUESTIONS PRODUCED UNDER TEXT-BASED AND KNOWLEDGE-BASED CONDITIONS

The data for this study came from questions generated by students on the topic of endangered species. In the text-based condition, one mixed Grade 5-6 class's students selected reference material and perused them before generating questions to guide their further study. In the knowledge-based condition, a comparable Grade 5-6 class was presented with a topic, and students went directly to generating questions. The sets of questions generated under the two conditions were randomly intermixed, along with questions drawn from published curriculum materials, and were rated according to (a) the complexity of search required to answer the question, (b) how interesting the question was to the rater, (c) the extent to which the question called for a factual response versus an explanation, and (d) how much pursuit of the question could be expected to contribute to learning. In accordance with our earlier informal observations, we predicted that questions produced under the knowledge-based condition would call for more complex search (because they would not be limited to kinds of information known to be available in the resource material), would more often call for explanations rather than factual responses, would be generally more interesting, and would hold greater promise for student learning.

Method

Participants. Participants in this study made up two combined Grade 5-6 classes in an inner-city elementary school serving an ethnically and socioeconomically heterogeneous population, with a higher-than-average representation of children from educationally advantaged homes. Assignment of students to the two classes was reportedly random, and students' equivalence was confirmed by standardized achievement test data to be reported later. Both classes were experimental classes in the development and evaluation of CSILE (Scardamalia et al., 1990; Scardamalia et al., 1989) and, as indicated previously, were accustomed to generating questions about topics being studied.

Compiling of question sets. The questions used in the study were compiled as follows:

1. *Text-based questions:* We interviewed teachers and asked them to identify a recently completed unit that might fit the text-based model-that is, a unit in which students had been instructed to record questions in the CSILE database after some preliminary examination of materials related to the unit. A unit on endangered species carried out in one of the classes best conformed to these requirements. Accordingly, we extracted all questions from the endangered species database, obtaining 104 questions from 20 contributors.

2. Knowledge-based questions: We did not depend on naturally occurring data from the database to compile this question set. Instead, we specifically asked students in the other class, which had not studied endangered species, to write questions

reflecting what they wondered about or needed to know to advance their understanding of endangered species. They were told not to concern themselves with whether they could answer the question: It was fine if the question was so hard that it would challenge experts in the field. They had no access to reference material. This constitutes a knowledge-based condition in that the students' prior knowledge provided the only basis on which their questions could be formed. The exercise was done with pen and paper, not on the computers, and took approximately 50 min- 5 min of introduction and 45 min to write questions.

A total of 150 questions was produced by 28 students. Unlike the questions from the text-based condition, a large number of questions collected in the knowledge-based condition reflected political or social concerns, for example: "Could we teach our children not to be so cruel with all the people around them being so cruel?" and "Why must we choose forests and countrysides to build more and more cities? Don't we have enough?" To obtain a question set comparable to that produced in the text-based condition, two raters sorted the sociopolitical questions from the others, settling disagreements (which occurred on only 6 questions) by discussion. The sociopolitical questions are not considered further in this article, for they open up another aspect of school learning that cannot be adequately discussed in the confines of this article. Analyses are all based on the remaining set of 82 natural-science-related questions.

Published curriculum questions. To serve as markers that would permit judgment as to whether student-produced questions as a whole were superior or inferior to questions that would normally be posed by a teacher, we looked for representative questions from published curriculum materials. The most appropriate material we could find relevant to the topic of endangered species was a unit entitled *Wildlife in Jeopardy* from the Federation of Ontario Naturalists (1984). After we eliminated simple recall questions and questions asking for personal opinions, six discussion questions remained. These were included in subsequent analyses.

Rating scales applied to questions. Four scales were used to judge the educational value of questions for the three experimental conditions.

1. *Knowledge Advance*: Raters were asked to judge how much understanding a Grade 5-6 student might gain from obtaining an answer to each question. The 4 points on the scale were *no contribution* (1), *minor addition to knowledge* (2), *significant addition to knowledge* (3), and *advance in conceptual understanding* (4).
2. *Fact/Explanation*: this was a 4-point scale, ranging from *searching for a rather trivial bit of factual information* (1) to *definitely searching for causal or explanatory information* (4).
3. *Interest*: Raters were asked how interested they would be in pursuing answers to the students' questions. The 4-point scale ranged from *no interest* (1) to *high interest* (4).
4. *Complexity of Search*: This 4-point scale ranged from *I would not need to research this. I know the answer already* (1) to *Coming up with a satisfactory*

answer would be a significant challenge requiring integration of complex and possibly divergent information from multiple reference sources (4).

Procedure. Because of the large number of items involved, the rating of items was carried out in two phases. In the first phase, the 104 text-based questions were rated on the Knowledge Advance Scale. This rating was done by having students in a graduate class in education rate subsets of 20 questions each, with the result that each question was rated by two raters.

For the second phase, a set of 100 items was created, comprising the 82 natural science items produced under the knowledge-based condition and 18 marker items. The marker items consisted of the 6 published curriculum questions and 12 items selected from the 104 text-based questions. The 12 items were selected to provide markers for the different levels of Knowledge Advance ratings obtained in the first phase. Only items on which the two raters agreed were considered. Out of 56 items rated 1 by both raters, six were randomly selected as markers. There were only three items that both raters rated 2, and three items that both raters rated 3. These items were also included as markers. There were no items in the text-based set that both raters rated 4. It may be noted that higher rated questions were proportionately overrepresented among the marker items. The mean Knowledge Advance rating for the whole set of 104 text-based items was 1.32, whereas the mean for the 12 marker items was 1.75.

The 100 items for the second phase were randomly ordered and not identified by source. The items were then rated by a graduate student in applied cognitive science. To increase the independence of ratings, the rater was blind to conditions under which questions were generated, and items were rescrambled for each scale. In addition, one of the authors rated all the items on the Knowledge Advance Scale. The average of the two ratings per item (reliability, based on coefficient a = .75) was used in reported analyses.

Results

As indicated in Table 1, questions generated under the knowledge-based condition received the highest ratings on all four scales – Knowledge Advance, Fact/Explanation, Complexity of Search, and Interest. Questions drawn from published curricula are intermediate on these scales, and questions from the ext-based condition are lowest. The differences between the knowledge-based and the text-based conditions are significant at the .01 level for each dimension. This is especially noteworthy given that, as explained in the preceding section, higher rated questions were overrepresented in the subset of text-based questions used in the analysis.

More important than mean item quality, however, is the actual number of items generated in a class that are judged to be educationally worthwhile as guides to study and inquiry. In the text-based condition, 4 of the original set of 104 questions (4%) were rated 3 or higher, indicating that obtaining an answer to the question would produce a significant addition to knowledge or an advance in conceptual understanding. By contrast, 38

questions (46% of the natural-science items) produced in the knowledge-based condition were rated at this level.

TABLE 1
Mean Quality of Questions for the Endangered Species Topic Across Three Conditions of Question Generation

	Condition					
	Wonderment/ Knowledge-Based Questions		*Text-Based Questions*		*Published Curriculum Questions*	
Scale	*M*	*SD*	*M*	*SD*	*M*	*SD*
Knowledge Advance	2.52	0.788	1.58	0.734	1.75	0.419
Fact/Explanation	2.89	0.906	2.08	1.084	2.33	0.516
Complexity of Search	2.99	0.920	2.33	0.492	1.83	0.408
Interest	2.81	1.114	1.75	0.965	1.50	0.548

To test the extent to which quality of questions might be attributable to general academic ability, we correlated the average Knowledge Advance rating of each student's questions with the student's total score for language and mathematics subtests of the Canadian Test of Basic Skills. The correlation was .03 for 19 students contributing questions in the text-based condition and .39 for 22 students contributing questions in the knowledge-based condition (neither correlation reached significance at the .05 level). There is thus a suggestion of a positive relationship in the knowledge-based condition but one that can account for only a small part of the variation in question quality. General academic ability does not account for the difference between conditions, either. The mean achievement test raw score total for students contributing questions in the text-based condition was 32; the corresponding mean for the knowledge-based condition was 33, $t(37) < 1$, $p > .50$.

Discussion

When students produced questions on the basis of their own knowledge in advance of being exposed to any curriculum material on the subject of endangered species, they produced questions of generally higher quality than those produced by comparable students who had already examined resource material on the topic. Questions produced in the knowledge-based condition were judged significantly superior in their potential contribution to knowledge, in their focus on explanation instead of fact, in requiring more complex information searches, and in being more interesting.

It should be noted, however, that the two conditions differed in several ways, so that it is impossible to isolate a causal factor. We do not know, for instance, what would happen if students were given prior exposure to material, as in the text-based condition, but were

otherwise treated as those in the knowledge-based condition. In any real school situation, we must assume that several factors will conspire to influence children's questioning. As Keil (1989) noted, a variety of evidence indicates that children are heavily influenced by the recency of information. Thus, recent exposure to material on a topic is likely to bias the questions children ask, regardless of instructions. The present results suggest that this bias is likely to be unfortunate, especially regarding the educational potential of the questions. In addition, children by the middle years of elementary school are likely to be sophisticated enough to censor their questions, depending on what they expect the consequences of asking them to be. If students are to be held accountable for seeking answers to the questions they ask, it is to be expected that they will adopt strategies to minimize risks of failure or overwork.

Consequently, in real school situations, where it is intended that children's questions have curricular consequences, knowledge-based questioning should probably be thought of as an ideal that can only be approximated. The present results may be taken as support for pursuing this ideal-that is, for trying to direct students' attention to what they need or desire to know rather than to question asking per se. Under the knowledge-based condition, encouraged to give free rein to their curiosity, a class of elementary school students produced a total of 38 questions (in addition to those expressing sociopolitical concerns) judged to be of substantial education value-surely enough questions to form the basis of a worthwhile unit of study, provided a way can be found to identify and make use of those questions.

STUDY 2: BASIC QUESTIONS AND WONDERMENT QUESTIONS

On the topic of endangered species used in the preceding study, children seemed to have enough prior knowledge to begin asking worthwhile questions. Although they lacked much specific information and may have had misconceptions (e.g., believing that slaughter by humans was the main cause of endangerment), they at least had a general idea of what it meant for a species to be endangered and of the social importance of the topic. How well would question asking fare on a less familiar topic? Previous experience in working with students in the CSILE context led us to expect that, under conditions of low prior knowledge, students would ask different kinds of questions but educationally worthwhile questions, nevertheless.

We selected the topic of fossil fuels for several reasons. First, one of the two Grade 5-6 teachers with whom we work did a unit on fossil fuels. The database showed a good deal of research effort devoted to basic issues such as "What are fossil fuels?" Second, the other teacher had never completed a unit on fossil fuels and believed that his students would have difficulty with the topic. Further, his students were the same students who had generated the text-based questions for endangered species.

Ideally, the class that had studied fossil fuels should have produced text-based questions, so that a study parallel to the preceding one could have been carried out. However, partly because of the unfamiliarity of the topic, the teacher had not called for the students to produce questions, and only one student had done so spontaneously. Consequently, the

present study deals only with the set of questions generated by the other class under the knowledge-based condition of having had no prior exposure to curriculum material on the topic. The focus of the study, accordingly, is not on comparison of conditions but on the nature of the questions generated.

Method

We presented the knowledge-based question-asking task in exactly the same manner as in Study 1. Our expectations that we were dealing with a low-knowledge topic were confirmed when one student asked "What are fossil fuels?" and many students accentuated that question with nods. We asked if anyone knew what fossil fuels were. Two students raised their hands, and one volunteered the definition, "Fossil fuels are fuels that come from the ground." One child asked if oil was an example, and another child said "yes." The question-generating session took 30 min: 5 min of introduction and 25 min to write questions. Questions were rated, using the same scales and procedures as in Study 1.

Results

Students generated 104 questions for the fossil fuels topic – an average of 5.5 questions per student, almost exactly the same as the average of 5.4 per student under the comparable condition for the topic of endangered species. Lack of domain knowledge, therefore, did not seem to hamper students in generating questions. Indications of the students' limited knowledge about fossil fuels did appear, however, in the kinds of questions asked.

More than half of the questions from the fossil fuels condition represent what we call *basic information* questions and *uneducated guesses*. Basic information questions include the following, with the number of students asking some version of it in parentheses:

Basic information questions (N = 39 questions)
- What are fossil fuels? (7 questions)
- What are fossil fuels made of? (5 questions)
- Why the name *fossil fuels*? (7 questions)
- What are the uses of fossil fuels? (6 questions)
- Where do fossil fuels come from? (5 questions)
- Where are fossil fuels found? (5 questions)
- What are different types of fossil fuels? (4 questions)

These questions, it may be noted, have a textbook quality to them; they seem to get directly at the kinds of information normally conveyed in basic textbook or encyclopedia treatments of a topic.

Uneducated guess questions are yes-no questions that seem to have a similar motivation to obtain basic orienting information, except that they take the form of shots in the dark at possible answers. The 18 questions of this type took one of the following forms:

Is _____ (e.g., water, lava, chalk) a fossil fuel?
Is _____ (e.g., electricity, minerals) related to fossil fuels?

We call the remaining 47 questions *wonderment* questions. They reflect curiosity, puzzlement, skepticism, or a knowledge-based speculation, in contrast to a groping for basic orienting information. Examples of wonderment questions are given in the right-hand column of Table 2. Matched with them are basic information or uneducated guess questions asked by the same individuals. Thus, it is evident that the two categories of questions are not characteristic of different kinds of students. The same students ask questions that seek basic information that will orient them to a topic and ask questions that show active thinking in which what they already know is used to probe beyond the basics of the topic.

Basic information questions were much less evident in the endangered species set. The only recurrent question of this type was, "Why are _____ (e.g., cougars, condors) endangered?" (5 such questions appeared). No student asked the most basic question, "What is an endangered species?" Presumably, they all had this basic understanding and were able to concentrate on wonderment questions such as, "How do scientists count a species so they know when it is endangered?"

Although the less familiar topic of fossil fuels produced a majority of questions at the basic level, there were, nevertheless, 16 questions rated as having the potential to produce an *advance in conceptual understanding*. This amounts to 15% of the questions-greater than the 4% produced on endangered species in the text-based condition but less than the 46% produced in the knowledge-based condition. All 16 of the highly rated questions were of the wonderment type. These questions were not the product of a student elite. The correlation between Knowledge Advance rating and achievement test total was only .32 (non-significant). Every student who produced a question receiving the lowest rating (*no contribution* or *minor addition to knowledge*) also asked a question that at least one rater scored as having potential for an *advance in conceptual understanding*.

Discussion

Considered along with the findings of the preceding study, the results of this study show that, when children ask questions in advance of studying a unit, they appropriately adjust the kinds of questions they ask according to their level of knowledge. If they already have a basic understanding of the topic, as with endangered species, they ask questions that have potential to extend their conceptual understanding. If they lack elementary knowledge, as with fossil fuels, they also ask questions of a basic type: What is it? Where is it? What causes it? The asking of such essential questions, however, does not preclude their also asking wonderment questions of a challenging and stimulating kind.

Level of knowledge, in this context, has to be judged from the students' point of view. Whether, in any absolute sense, students knew more about endangered species than about fossil fuels cannot be judged from the available data and is perhaps indeterminable. Also,

it is conceivable that if the topics were put differently, so that endangered species became species extinction and fossil fuels became oil, gas, and coal, effects might have been reversed. What counts is the students' own perceptions of what they know, and this depends on what is in fact activated rather than on what could potentially be activated by different prompts. Perhaps it should be concluded that children appropriately adjust the kinds of questions they ask according to their perceived level of knowledge.

TABLE 2
Basic Information and Wonderment Questions Asked by the Same Students

Student	*Basic Information Questions*	*Wonderment Questions*
No. 1	Is cloth a fossil fuel? Is steam a fossil fuel? Is fire a fossil fuel?	Can you make different fossil fuels by mixing other fossil fuels? How long do most fossil fuels last?
No. 2	Does metal have anything to do with fossil fuels? Are fossil fuels found in food? Plastic	Did the caveman know what fossil fuels were? Are fossil fuels still being explored by scientists?
No. 3	Why is it called fossil fuels? What creates fossil fuels?	Are fossil fuels found everywhere or does it have to be a certain climate? Is there anything that will only run with fossil fuels? What is the difference between fossil fuels and other types of fuels?
No. 4	Is heat a fossil fuel? Is air a fossil fuel?	When was fuel discovered?
No. 5	Is food a fossil fuel? Are some things alive and fuels?	Is everything either a fuel or needs a fuel?
No. 6	Is lava a fossil fuel? Are some things alive and fuels?	How does fuel energize cars, boats, planes, and so on?
No. 7	Does the word *fossil* in fossil fuel have anything to do with fossils?	What are all the things that are made of fossil fuels?
No. 8	Does this fossil have to do with dinosaurs? Do you use fossil fuels when you have a barbecue?	Does fossil fuel affect the ozone layer?

STUDY 3: CAN STUDENTS IDENTIFY THE EDUCATIONALLY MOST VALUABLE QUESTIONS FROM AMONG THOSE THEY GENERATE?

Given that students generate more questions than they could investigate within the time normally available for a unit and that these questions vary greatly in their judged potential for aiding knowledge advancement, it becomes important to find out how successfully students can select questions to pursue. In this study, we had students rate selected questions used in the preceding studies according to how much they thought pursuing those questions would advance their knowledge. These ratings were then correlated with the comparable ratings made by experimenters and by the students' own teachers.

Method

Student ratings were obtained on subsets of the previously generated questions on endangered species and fossil fuels. Twenty-two questions were selected on each topic. Rather than selecting questions randomly or from extremes, we used judgment in selecting questions that covered the full range of rating levels and types (wonderment vs. basic knowledge) and that reflected the major themes of the full set of questions, but we avoided questions that contained obvious surface cues that would influence quality judgments, such as length of question or use of technical vocabulary.

Forty-nine Grade 5-6 students from the same classes that had generated the questions originally were randomly assigned one or the other set of 22 questions to rate on a 10-point scale-ranging from *little advance* (1) to *big advance* (10)-the degree to which answering a particular question would help in making an advance toward becoming an expert on the topic. Twenty-five students rated endangered species questions, and 24 rated questions on fossil fuels. These ratings were correlated with previous experimenter ratings of the questions on the Knowledge Advance Scale. Knowledge Advance ratings of the 22-question sets were also obtained from the two Grade 5-6 teachers whose classes were involved in the study. Finally, two children (one from each of the participating classes) were interviewed as they rated questions, so as to obtain protocol data on the criteria they used in judging the learning potential of questions.

Results

We first considered how the average rating of each question by children correlated with the Knowledge Advance ratings of those questions by experimenters and teachers. For the 22 endangered species questions, student ratings correlated .89 with experimenter ratings and .69 with teacher ratings. Experimenter and teacher ratings correlated .71 with each other. For the fossil fuels questions, student ratings correlated .56 with experimenter ratings and .67 with teacher ratings, with experimenter and teacher ratings correlating .63 with each other. In both cases, the children agreed with the adult raters about as well as the two groups of adult raters agreed with each other.

The generally lower level of agreement on fossil fuels questions reflects disagreement about the educational potential of basic information questions. All three groups of raters tended to agree on highly rated wonderment questions. With obviously naïve questions such as “Is water a fossil fuel?”, however, there is understandable uncertainty as to whether the question should be judged of low educational value, because it deals with a simple and easily settled matter of fact, or of high value, because it brings up a basic conceptual issue.

The problem of judging the value of basic-level questions is compounded when the judges are the students themselves, who lack the knowledge required to see the important conceptual issues that my lie behind naïve questions. This difficulty was evident in one of the two students interviewed. He declared himself to have no knowledge of fossil fuels. In response to the question, “Is there such a thing as dinosaur fuel, or is it all used up?”,

he exclaimed, “See, this is just stupid! What do dinosaurs have to do with fuels?” He gave that question the lowest possible rating. On the other had, he gave the question, “Is lava a fossil fuel?” a high rating because he thought lava might be a fossil fuel. This student seemed frustrated by his lack of knowledge, rejecting questions that he could not relate to his knowledge and approving questions that seemed to fit with what he believed.

The other interviewed student, however, although apparently no more knowledgeable than the first student, showed considerable sensitivity to the importance of basic knowledge in contrast to isolated factual information. This child seemed to respond with genuine delight to some questions, exclaiming “Oh, that would really give me a new way to think about this!” This reaction only appeared for items to which all raters (adult and students) accorded high scores. The other typical reaction to items with agreed-upon high ratings was, “It’s important because it gives you the big picture. If you knew this, you’d know or be able to figure out these other questions.”

For the topic of endangered species, on which this student regarded himself as quite knowledgeable, he consistently gave a minimum rating to items that dealt with one animal, explaining “It’s just one animal…. It doesn’t tell you about the big picture.” In contrast, with the fossil fuels topic, comparable items dealing with one substance (“Is lava a fossil fuel?” “Is water a fossil fuel?”) were given a rating of 4 out of 10. He explained, “You need to know… The bigger question is ‘What is a fossil fuel?’” Despite his severe knowledge handicaps (he did not know what fossil fuels were or whether water was a fossil fuel), he was able to appreciate the significance of questions produced by students as naïve as himself, recognizing their relevance to a basic understanding of the domain.

The contrast between these two students is highlighted in their responses to the question, “Do we have fossil fuels in our bodies?” The first student responded, “How could I know? I don’t know anything about fossil fuels.” The second responded, “I’d rate it a 4 because it’s basic information and you need to know. But it’s not a question that really helps you think.” Despite their different orientations, both students responded positively to wonderment questions such as, “If fossil fuels are from the earth, how did they manage to get to the sun, the stars, and other galaxies?” The first student responded, “Yeah, I’d like to know.” The second responded, “Did they? Gets you thinking. It’s a good question.”

Overall, individual students’ ratings of questions correlated less well with adult ratings than did the averaged student ratings. For endangered species questions, the median correlation of individual student ratings with experimenter ratings was .60 (n = 25 students), with a range of -.37 to .90. For fossil fuels questions, the median correlation for 24 students was .40, with a range of .14 to .66. These correlations compare with the .89 and .56 correlations based on combined student ratings. Thus it is apparent that, although there is a central tendency for students to agree with adults in their assessment of the educational value of questions, there are some students who do not agree at all.

Discussion

Students and adults seem to to agree that the investigation of wonderment questions can lead to significant conceptual advance. On the topic of endangered species, in which students already had some basic understanding, there was a generally high level of agreement among children and adults about which questions are of greater or lesser educational value; with questions on fossil fuels, however, a low-knowledge topic, children seemed to have difficulty distinguishing naïve questions that are merely ill conceived from naïve questions that raise important conceptual issues. Because adults do not agree very well on this matter either, it might be considered to be of no great concern. The interview data suggest, however, that some students may go badly awry if they judge questions according to how well they fit with their own (severely limited) knowledge).

The central tendency data, as well as the second student interview, indicate that there is substantial educational wisdom available in a group of students, even when they do not know much about the topic whose study they are contemplating. There is an obvious problem, however, regarding how this wisdom is to be marshaled. Pooled ratings by students showed medium to high agreement with adult ratings of the educational value of questions, but the pooled ratings are a statistical creating that does not correspond to any consensus that actually exists among the students. Ratings by individual students varied greatly in their agreement with adult ratings and with one another. What seems to be required, if students' questions are to function successfully in schooling, is a social process that allows the wisest judgments to work their way forward. In the next section, we examine case material that suggests this may not be such a formidable problem.

Pursuing answers to text-based and knowledge-based questions. We asked teachers of the children who participated in the studies described earlier to classify questions the children produced. Categories were "I know the answer already," "I don't know the answer off the top of my head; it is not, however, a challenging research question," and "I could profitably be engaged along with the students in research on this question." The teachers put about half of the questions into the last category. It is tempting to envision an educational model that can take advantage of this result-whole groups, including the teacher, working together investigating questions of mutual interest. This would be true "cognitive apprenticeship" (Collins, J.S. Brown, & Newman, 1989), where master and apprentices pursue the same goals, rather than a contrived apprenticeship, in which the cognitive goals for the students have already been achieved by the teacher.

Such a model of collective inquiry, however, lies at the far end of a continuum, even the near end of which represents a significant change from the typical situation in which the process of schooling is driven by the teacher's asking of text-based questions. The near end of the inquiry continuum sees students individually asking and then seeking answers to text-based questions. A farther point on the continuum sees students asking text- and knowledge-based questions of one another, which constitute goals for further inquiry. Still farther out (and perhaps as far as can be gone without a revolutionary change in the structure of schooling), knowledge-based questions may capture the interest of a growing number of students and teachers and form objectives for cooperative inquiry. Perhaps this

extreme version of question-driven learning becomes more realistic, however, as electronic networks make it feasible for classrooms to be connected with outside experts and information resources and as software is developed to support collaborative inquiry (Newman, 1990; Scardamalia & Bereiter, in press).

GENERAL DISCUSSION

Before discussing educational implications of the results, we need to consider the limits on the generalizations that may be drawn from them. The results are based on students in Grades 5 and 6 who tended to be from advantaged backgrounds and whose recent experience had been with an educational program in which self-generated questions were actively encouraged and given a significant role in the curriculum. We do not know whether similar results could be obtained with younger or older students, with ones from less academically oriented backgrounds, or with ones in different kinds of school environments. We are inclined to be optimistic on these points. There are reports from various experimental efforts about collective inquiry indicating that students do ask educationally productive knowledge-based questions (A.L. Brown & Campione, 1990; Goldman & Newman, in press; Lampert, 1988; Roth, Anderson, & Smith, 1987). What we do not know, however, is whether there are critical characteristics of the school environment, common to these experimental projects, in the absence of which student-generated questions are unlikely to hold much promise.

In view of these limitations, the present results can only be claimed to show that there is substantial educational potential in student-generated questions, although the limiting conditions on this potential are yet to be determined. One thing that does seem clear, however, is that this educational potential extends beyond that envisaged by research on question asking carried out within the prose learning tradition. As reviewed by Wong (1985) and by Rosenshine and Chapman (1990), the goal of instructional interventions in this tradition seems to be teaching students to ask themselves the questions that are customarily asked by teachers or textbooks. We take the research to show that children can learn to do this and that there are gains in text comprehension when they do it. This benefit from getting students to ask text-based questions is not to be disparaged. Especially when the focus is on developing comprehension strategies, as in most applications of reciprocal teaching (A. L. Brown & Campione, 1990), it may be important to encourage text-based questions-questions that can be answered from the text being read rather than depending on information from outside the text. With knowledge-based questions, however, there is the potential to go beyond using questions as a way of extracting information from already available texts and using them as guides to the construction of knowledge derived from various sources and from private and collaborative reflection.

The results of the present studies lead to something of a dilemma, however, when it comes to designing practical means of exploiting the full potential of student-generated questions. The studies indicate that, under the right conditions, children can produce questions that could usefully direct their inquiry and study, but the condition that best elicited such questions was one in which children could assume that their questions

would not be used for such purposes. On the surface, it appears that the very effort to structure the curriculum so that students' questions have a directive function discourages students from producing the kinds of knowledge-based questions that can best serve that function.

One way out of the dilemma, as espoused by educators in the progressive education/open education tradition, is to avoid imposing any activity structure that might hamper the natural workings of curiosity. As Lilian Weber (1971) put it:

> A child can be active only in the free situation…. A child must find a solution for the problem *he* was searching to understand, a solution that makes sense of the observations *he* has made. Discussion may help a child locate his problem more clearly but the adult cannot decide in advance on the suitable solution or even the path to a solution. (pp. 184-185)

This approach requires extreme individualization of activities, an ability of the teacher to "think with" each child individually (Weber, 1971, p. 229), plus extraordinary confidence in the power of students' curiosity to sustain learning activity. Even if this approach achieves the kind of student engagement that is often proclaimed in testimonials, it leaves several unsolved problems. As results of the present studies show, children readily ask far more questions than they can pursue, and these questions vary greatly in their educational potential. The first question that comes to mind is not necessarily the one most worth pursuing. Consequently, there is need for a divergent phase in which many questions are generated and a convergent phase in which those most worth pursuing are sorted out. This implies at least some formality of procedure if the process is to work in a classroom setting. There must be a means for students working on the same or related questions to interact in ways that drive inquiry to deeper levels rather than proliferate shallow conjectures. Finally, there needs to be a way for new questions that arise in the course of inquiry to have an impact on its subsequent course.

A networked computer system like the current version of CSILE provides a convenient medium for the more divergent aspects of inquiry-generating questions and hypotheses and reacting to the questions and ideas of others. Its advantages over a lively class discussion are that contributions are preserved and more students get a chance to be heard. The two are not in opposition, however; we find that an alternation between live discussions and individual work at computer servers to capture the motivational and cognitive advantages of both media.

A major challenge for both face-to-face and electronic media, however, is to help sustain inquiry in a progressive way. A good example of progressive inquiry sustained by questions comes from Miyake (1986). Miyake had pairs of adults try to discover and explain the workings of a sewing machine. She found it was common for one member of the pair to drive the inquiry by asking for an explanation of the mechanism accounting for a function. An explanation of stitching might be that the thread coming from above is wrapped around the thread coming from below. The questioner asks how that is done. An explanation might be that the thread from above is passed around the bobbin, which holds

the lower thread. The questioner then asks how the thread gets around the bobbin, which leads to an analysis of the bobbin case, and so on to levels of more complete explanation.

Progressive inquiry seems to be rare in schoolchildren, however. Suchman (1962), using an inquiry format in which students asked yes-no questions in order to converge on an explanation of puzzling physical phenomena, found that the students tended to be satisfied as soon as they had identified a relevant factor, being unconcerned that the factor could not account for all of the observed phenomena. Examples of progressive inquiry have occurred among CSILE students with increasing frequency, but they are still not the norm. In a notable case of programming inquiry, one student's note reported that sponges have three ways of reproducing. A flurry of notes and comments followed this startling revelation, with the key question being, Why do they need more than one way to reproduce? In all, 12 notes and comments were produced. Various hypotheses were advanced, generally having to do with survival of the species. Ordinarily the inquiry would have ended at that point. In this instance, however, answers to the original question raised an additional, deeper question for one student: If having several ways to reproduce is so advantageous, why don't other animals have them as well? The student kept asking this question while commenting on other students' notes. For the most part, the question drew no response, but through persistence the student finally got a few others to offer answers. In the meantime, the questioner developed her own theory on the matter, which was that only simple animals like sponges could reproduce by budding and regeneration. This theory was presented as a note that drew further comment.

We take this example to be a modest model of how students' questioning ought to work in school: A question arises spontaneously rather than on demand. Although it may not be intrinsically more valuable than many other questions that arise, it happens to gain the interest of a number of students. (It is surely no accident that the question that attracted such interest in our example dealt with sex and reproduction-themes that Schank, 1979, would classify as absolutely interesting as well as involving relative interest due to the unusualness of the sponge's reproductive repertoire.) There is a means for students to interact in pursuing the question, for criticism to be brought to bear on proposed answers, and for advocates of particular questions or answers to promote their causes. Although a question may not be pursued very far (no one ever produced a factual case for why sponges are especially in need of alternative ways to reproduce), it is pursued far enough to yield educational benefit. In the present instance, the benefit was in applying adaptationist reasoning to a novel case.

In the sponges example, however, progressive inquiry was achieved through the unusual persistence of one student. We doubt that there is any straightforward procedure for making this happen. Yet progressive inquiry is sustained in the sciences and scholarly disciplines, often with very little in the way of formal procedures. What seems to be required is a community in which the advancement of collective knowledge is highly valued and individual contributions have the possibility of being immortalized. Schooling, in its several common varieties, lacks these characteristics, and so it should not be surprising that the pursuit of knowledge is either reduced to a routine task or is left to individual initiative. Our hope for the kind of technology represented in CSILE is that

it will provide a basis for classrooms to be restructured as knowledge-building communities (Scardamalia & Bereiter, in press). This would mean that collective knowledge (as represented, for instance, in CSILE/s communal database), rather than work, activities, or private interests, would be at the center of attention. In such a community, questions that push against the limits of current knowledge would assume a natural importance, as they do in the learned disciplines.

As an indication of how this visionary scheme might be pursued in practice, we now describe a new approach being taken by one of the teachers who participated in the studies reported here.1 The approach was partly motivated by the results of this research, and it represents an interesting slant on dealing with the dilemma of an activity structure that inhibits the very kinds of questioning it depends on.

Students work in groups, tackling a broad topic such as human biology. As a first step, each student produces, in consultation with the teacher and group members, a question that the group is expected to pursue. The questions, such as "How does the heart work?", become problem statement, which act as the heading for a note in the CSILE database to which all group members have authoring access. A distinctive feature of this note is a provision for students to add entries labeled "I need to understand." Using this label, group members can enter anything they feel needs to be understood in order to answer the main question. For instance, with respect to how the heart works, one student indicated a need to understand "why the blood has to move around in the body," which is fundamental to making sense of the circulatory system. Other types of contributions to the group note may be labeled "new information," "comment," "reference," or "my theory."

The group approach removes some of the onus of finding answers to one's own questions. Initial results suggest that "I need to understand" elicits knowledge-based questions of higher quality than those elicited by the means used in the present studies. Perhaps it implies less of a commitment to being able to find a specific answer and, therefore, removes the motivation to stick to text-based questions. The effectiveness of "I need to understand" may well depend, however, on its occurring within a context of group support for advancing understanding. We have tried to show in this article that children can ask and recognize questions that push against knowledge limits. As every researcher knows, pushing beyond those limits is an effortful and risky business, hence the need for some kind of classroom society in which pushing beyond the limits of current understanding is a normal and mutually supported enterprise.

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