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"WHAT HAVE YOULEARNED?": CO-CONSTRUCTING THE MEANING OF TIME

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Have you ever tried making a water clock from pieces of wood left over from renovation, a plastic spoon, a yogurt carton and bits and pieces of string? At the suggestion of their teacher, the first author constructed such a device— with the help of the directions in a junior science guide— and took it to the combined grade three and four class in which the two authors were collaborating in a study of the grade three students as they worked on the theme of time. When it was finally set up, the teacher asked some of the children who had been watching to demonstrate how it worked to the rest of the class. Unfortunately, it failed to work as expected. However, suggestions for fixing it were not slow in coming and soon an animated discussion was in full swing, as competing proposals were put forward, justified and evaluated. By the end of the day, some of the most enthusiastic engineers had succeeded in making it work.

We want to hold on to this event for a moment, and say a little more about its significance, as we perceive it. For it has come to function as an icon for us as we have thought about the actuality of classroom activity from the perspective of its role in bringing the resources of the past to bear in equipping each new generation of students to meet the challenges of their future. As we shall try to show, this unplanned situation epitomized many of the characteristics of the social constructivist model of learning-and-teaching which we wish to explore through a more detailed examination of some of the episodes that occurred during the course of these students' study of time.

During the preceding weeks, the children we had been observing had engaged in a variety of activities designed to help them understand the need for a standard method of measuring time. They had also learned about some of the earliest timing devices by constructing simple versions for themselves and then using them to measure how long it took them to perform an activity such as walking round the room. The model water clock, complete with its striking mechanism, was intended to add a further dimension to their study, by showing how the problem of marking the passage of time in a regular manner could be solved by the use of a number of simple mechanical principles in combination. It was, one might say, a way of reconstructing the past with the intention that the children should grasp the principles involved in order to be able to use them in solving problems in the future.

However, as it transpired, the imperfect workmanship succeeded in teaching another lesson. Instead of serving merely as a demonstration of how the problem might have been solved in the past, the water clock became a problem in its own right. To it the children brought their own original and creative solutions, testing them in debate and subsequently in action, until they had created a functioning device that was better than the one the adult had originally constructed. What they demonstrated in the process was that the most effective way to foster children's thinking and problem-solving ability is to present them with a challenge that engages their interest and invites them to create their own solutions. They certainly benefited from the experience, but probably the person who learned most from this incident was the one who had designed the model as no more than a demonstration. Before going on to look at further episodes from these children's study of time, therefore, we should like to develop these ideas a little further by presenting a brief account of recent work in sociocultural theory, as it applies to learning and teaching in schools. We believe that the insights that this theory offers can help us understand, and perhaps reinterpret, some of the most enduring characteristics of classroom practice.

BRINGING THE PAST INTO THE FUTURE

Let us start with a quotation from Leont'ev, who, with Vygotsky, is one of the founders of sociocultural psychology. Describing the cultural continuity which makes human society uniquely different from that of all other species, he writes: "a special form of transmitting the achievement of preceding generations to the next takes place in human society; that is, the achievements are embodied in the material and spiritual products of human activities and specific human psychological abilities can be developed through the mastery of these products by each person" (quoted in Amano, 1991). More recently, Michael Cole has made a similar point: "Human beings live in an environment transformed by the artifacts of prior generations ... the basic function [of which] is to coordinate [them] with the physical world and each other" (1991 , p. 6).

Central to the thinking of this school, then, is the idea that the artifacts that were invented in the past to solve the problems that were encountered then can serve as a sort of external cultural memory, encoding the interactions of which they were previously a part and carrying their potential for solving similar problems into the present and future. In order to benefit from this legacy, however, each new generation has to be inducted into the cultural practices in which they are used and be able to recognize when and how they are relevant.

But it is not simply to physical tools that these writers refer, nor to such social practices as marriage customs or legal procedures. More important is the recognition that language, both spoken and written, and the uses we make of it for remembering, reasoning, evaluating, as well as communicating, are also cultural artifacts and practices, and that these, too, have to be learned and mastered through social interaction in the context of joint activity. Thus all the higher mental functions, as Vygotsky (1978 , 1981) called them, first exist and are encountered inter-mentally, in interactions between people; only when they are appropriated and internalized do they function intra-mentally, as a resource for individual thinking and problem solving.

Inspired by this theory, a considerable amount of research has taken place in recent years into the forms of adult-child interaction that facilitate children's cognitive and linguistic development (e.g., Newman, Griffin, & Cole,1989; Rogoff, 1990, 1992; Wells, 1986; Wells& Chang-Wells, 1992; Wertsch, Minick, & Arns, 1984). Vygotsky described this contingently responsive tutorial behavior as "working in the learner's zone of proximal development;" more recently it has been variously described as "scaffolding" (Wood, Bruner, & Ross, 1976) or "prolepsis" (Wertsch &

Stone, 1985). Whatever the term used, what is emphasized in all these accounts is the way in which the tutor (whether parent or teacher) takes the learner's attempt to perform some part of the task and appropriates it into her or his more mature version, thereby giving it a significance which it does not yet have for the learner. In so doing, the tutor both enables the learner to contribute as much as he or she is able to the performance of the task and, at the same time, to become aware of the functional relationship between the constituent actions and the goal of the task as a whole. From participation in such shared task performances, the learner in turn appropriates the tutor's version and, having internalized it, is eventually able to perform it on his or her own. In this way, knowledge, both substantive and procedural, that is first encountered and mastered in social interaction, becomes an intellectual "tool-kit" for thinking and problem solving carried out by the individual alone.

Thus far, we have concentrated on learning as the remembering of the past through the taking over of the achievements of previous generations. But, as the metaphors of "scaffolding" and "prolepsis" make clear, this theory also involves a kind of remembering of the future, as the teacher, based on his or her own past experiences, projects a more complete version of a task than the learner is currently able to achieve and assists and guides the learner's performance in such away as to bring that future about (Cole, 1991). Indeed, on a larger time-scale, education can be seen as a form of apprenticeship, as more mature members of a culture— parents, teachers and educational policy makers— drawing on their interpretations of their own remembered past experiences, project expectations about the future lives of the children in their care, and create opportunities for them to appropriate the cultural resources of knowledge and skills that they themselves have found important.

However, to place the emphasis almost exclusively on reconstructing the past for an imagined future has serious limitations. First, there is increasing likelihood that the future today's students actually encounter will be very different from that which we imagine; by equipping them only with the resources of the past, therefore, we will render them less able to solve the problems, unforeseen by us, with which they will actually have to cope. Equally important, if we emphasize tradition and authority at the expense of originality and creativity, we shall fail to do justice to the transformative nature of learning and to the possibility that this implies for change and improvement, both for the individual and for society as a whole.

Two further points must therefore be added to provide a more balanced account. First, it must be emphasized that internalization does not imply a simple copying from the outside in. In all cases, in taking over, or appropriating, a cultural artifact or practice, the learner necessarily constructs a new internal version, which builds upon and is shaped by what he or she can already do and understand. At the same time, in the process of internalization, the learner also "grows into" the organizing cognitive structures associated with the artifact or practice; this results in a modification of the individual's own cognitive organization and thus changes the way in which he or she perceives, interprets and organizes the world (Nicolopoulou, 1991; Rogoff, 1992). In other words, the outcome of the process of internalization is a transformation of the way in which an individual participates in a social practice, such that he or she is able to engage more effectively in the relevant activities.

Secondly, it is important to recognize that all action is creative, in the sense that each occasion of interaction with the social and material world is different from all previous occasions and demands a response which is unique to the particularities of the present moment. It may also be creative in the further sense that the solutions constructed for the problems encountered often go beyond previous achievements to create new artifacts which, in turn, have the potential to enhance the cultural resources to be used in solving future problems. Thus, just as the learner is transformed by appropriating the problem-solving resources inherited from the past, so can present problems be transformed by the new insights that learners are able to bring to bear on them. Therefore, if we are to make good use of the insights to be derived from sociocultural theory to enhance our understanding of the goals and means of education, a concern with cultural reproduction and continuity needs to be complemented by an equal concern with cultural renewal and an encouragement of the creativity that makes this possible.

The remainder of this chapter explores what these ideas might look like in practice, through a collaborative investigation undertaken by both authors into the learning and teaching that took place in one unit of work in science— the study of time which was referred to in the introduction. However, because of the limits of space, we shall focus mainly on a single event—the discussion which occurred at the end of the unit, in which the teacher and children reviewed the work they had done in the preceding weeks. As we have argued elsewhere (Wells, 1995), of all the components of an inquiry oriented curriculum approach, the final retrospective review is probably the most important— for both students and teacher in the opportunities it provides for them jointly to construct a common understanding of what has been achieved, and how, and to identify topics and issues that are recognized as needing further investigation. But before turning to the discussion, we must first provide some context by saying a little about the participants in the discussion and about their classroom environment.

The School and Classroom Context of the Investigation

The school in which this investigation took place is situated in an inner-city area in Toronto. Due to its location, close to Chinatown and also to a number of large corporate office buildings and hospitals, the students come from a wide variety of backgrounds. Some are children of relatively recent immigrants, who work in service jobs nearby; others are children of doctors, lawyers, and other professionals, who have chosen the school because of its reputation and because of the day-care facilities that it provides. It should also be noted that this school is one of the few that offers heritage language instruction, in Chinese and in Spanish, as part of its regular program; in the last few years, it has also included a black studies program as part of its curriculum. The makeup of the combined grade three and grade four class is fairly typical of the school as a whole. Children of Caucasian descent, for whom English is the first language, are in a minority, although most of those who are bilingual in English and another language have been resident in Canada since birth, or at least since they began to attend school. There are, however, several children who have arrived in the last year or two, and they are still receiving special help in learning English as a second language. The class also has several children who are withdrawn for additional help in literacy or with other special needs.

Although the class includes children from two grades (three and four), whose current levels of attainment span a very wide range, the teacher tries to create a single community in which each child is challenged to address the topic being studied at a level appropriate to her or his ability.

For much of the time children work in groups, sometimes self-selected and sometimes chosen by the teacher. In all cases, the groups are encouraged to develop their own ways of working cooperatively, but with the requirement that each child play a part in achieving the goal that is jointly negotiated. On the present occasion, as an experiment, the teacher has decided to divide the class, with one half engaging in a unit on forensic science and the other half making a study of time.

Since this study took place in January and February, the children already had some experience of engaging in sustained inquiry. In the previous term, they had done work in science on sound and on light and color, and in social studies they had carried out library-based research on a Canadian province or a foreign country. Concurrently with the work on time, they were also studying endangered spaces and species. Evidence of the resources they had used and of the meanings they had made with them was to be seen on shelves and tables in all parts of the classroom and displayed on bulletin boards around the walls and in the adjoining corridor. From these same sources it was evident that, wherever possible, connections were also made between these topics of inquiry and the children's work in math, literature, art and drama. The study of time should be seen, therefore, against the background of a curriculum that was both integrated and challenging.

Co-constructing the Meaning of Time

The discussion which is the focus of this chapter occurred at the end of the unit of study on time and served as an occasion for the children and their teacher to make connections among the various activities in which they had engaged and the artifacts of various kinds that had mediated both their practical activity and the sense that they had made of what they were doing. It started with the teacher gathering the children on the rug and inviting them to think about what they had learned during the preceding 5 weeks. Almost all the topics that were considered in the following 40 minutes were generated from this initial invitation. They are summarized in Table (1). The duration of each topic, in number of exchanges, is shown in parentheses in the final column.

Set out like this, the discussion can be seen to have had an impressive agenda, one that very few teachers would consider possible to treat in any depth with 8- and 9year-olds. What was it, then, that enabled this group of children to remain interested and involved from beginning to end of this long and challenging discussion? The first part of the explanation, we believe, is to be found in the rich variety of practical work that the children had engaged in, from which they had acquired first hand knowledge about several of the topics that were raised. Through the activities of attempting to invent a method of measuring time, experimenting with pendulums, and constructing either a "water-clock" or a "rolling-ball-clock," they had experienced, in practice, what it is to "do science." They had also found themselves faced with problems they had attempted to solve in a (relatively) principled and systematic manner. Personal experiences from outside the classroom provided a further source of information on which they could draw.

Table 1. Overview of the Review Discussion

Episode #	Topic	Initiator	# of Exchanges
1	Introduction: Personal responses	Teacher	3
2	Accuracy: Need for standard measurement – comparing methods used by different groups	Auritro	10
3	Processes of science: fair test, variables – reviewing experiments with pendulums	Bianca	20
4	Checking knowledge of units of time	Tema	16
5	Previous work with pendulums – personal recollection	Tema	4
6	Sources of power for clocks and timers – personal experiences	Bianca	4
7	Basis of units of time in earth's movements – demonstration using various artifacts	Teacher	13
8	Time zones –exploring personal anecdotes, using globe	Bianca	40

However, that is to tell only part of the story. As Driver (1983) argues, on the basis of observation of many classrooms in which children engage in practical activities in science, "hands-on" activities do not lead to the development of an understanding of scientific principles unless they are accompanied by "minds-on" activities as well. In this unit, numerous instances of such sense making occurred in the conferences that took place while the activities were being planned and in progress, and in class discussions that occurred after each one to underline the significance of what had been done. Limitations of space make it difficult to do more here than hint at the richness of these continuing discussions.

Mention must also be made of the various books the teacher had assembled, which the children had been encouraged to consult for specific purposes and to browse through more generally. Equally important were the science logs that the children kept, for these were another tool for sense making. Rather than simply using them to report what they had done, the children were encouraged to write in their logs about what they had learned and about their reflections on the experience; they were also encouraged to note questions to which they wished to obtain answers. Finally, mention must be made of the connections that were noted in passing between their science investigations and the work they were doing in mathematics.

This review discussion was not an isolated event, therefore, but a part of this teacher's overall approach to the learning and teaching of science in her classroom and, indeed, to learning and teaching in all areas of the curriculum. As she explained, there are three aspects of doing science that she wishes the children to gain from the work that they do in each unit: the concepts appropriate to the topic, the processes of observation and experimentation and of making sense of the results, and the language for talking, reading and writing about the topics that they study. One of the overall purposes of this discussion, then, was to continue to weave connections among all the three. However, an equally important aim was to bring together the meanings that individual children had been making, both alone and in their separate groups, and to construct a shared understanding of what had been done and found. By bringing her own more systematic knowledge of the various topics associated with the theme of time to this co-constructive process, the teacher also wanted the children to have an opportunity to take over some of the ways of talking and thinking about these matters that are practiced in the wider culture.

What we wish to explore, then, is the way in which these various aims were achieved in the moment-by-moment unfolding of this particular discussion. In the process, we hope to show how collaborative talk of this kind makes possible the co-constructive and transformative knowledge building that was described in the introductory section of this chapter. Furthermore, since discourse is itself a cultural artifact, which learners have to appropriate through participation in actual occasions of use, a close examination of selected episodes from this particular classroom discussion should enable us to gain a better understanding of how this process of appropriation takes place.

The Need for a Standard Method of Measuring Time

The teacher opens the discussion with a very general question: "What have you learned about time?" Tema, Emily, and Jamilla obviously hear the question as a request to tell about what they have personally learned, and each contributes an interesting idea.

1 Tema: It's not just everything is the same thing . some people might want to
set their clocks faster or slower or right on time

2 Teacher: Emily

3 Emily: Time does not have to be telled by clocks and watches we can-we also *
it can also have different sort of timers

4 Teacher: OK, we learned about different. types . of timers (writing on board) .
clocks or even watches, right?
And I think what Tema said I would rephrase it as time is a form of
measurement, right? (writing) a . form . of. measurement, right? just as
distance is a form of measurement.
What else did you learn about time?. anything else? Jamilla?

5 Jamilla: We learned that it um- you don't necessarily have the um- the coo- the
watches like um the, minute hand, the hour hand, the second hand,
you can also-you can also use water and <things like that> construct
watches and um . construct clocks and it doesn't have to be um um
someone- someone special makes them to be *

6 Teacher: Uh-hmm, right (accepting) So a timing device like a clock or watch ma not have the minute or hour hand, you can use the water . to represent the- the minute hand for example . or use something else to represent it. Yes, what else did we study in the whole unit of time?

7 Auritro: Counting isn't always accurate

8 Teacher: Counting is not accurate, so there are certain ways of. timing that some are more accurate and some are less accurate, for example like counting . What is more accurate than counting?

9 Bianca: Using the stop-watch

10 Teacher: Using stop-watches . What about the things you made? .. of the various things you've made what are some of the timing devices you all made?

In their idiosyncratic detail, these answers are not untypical of children, or even of adults, who lack experience of engaging in metacognitive talk. In these circumstances, they tend to provide answers that are at the "local and specific level." As is apparent here, an invitation to reflect does not in itself enable reflection. More has to be done. In fact, as is suggested by the research on adult-child interaction (Bruner, 1983; Cross, 1977; Wells, 1986), it is the follow-up to a child's contribution that is crucial for the development of a conversation; it is also this move, in particular, that makes a qualitative difference to what the child learns from the interaction as a whole (Wells, 1996). Here, in the teacher's follow-up moves in turns 4 and 6, it is evident that, as she echoes back what the children have said, she is doing three things. First, she is providing an opportunity for the children to discover how their contributions have been understood and giving them a chance to make a repair if needed. Second, whilst accepting the child's idea, she introduces an alternative way of articulating the response, thereby bringing it closer to the register conventionally used in the wider culture for "talking science" (Lemke, 1990). Third, and perhaps most important from the metacognitive perspective, she "steps up" the children's responses to a level of talking about their personal experiences in a way that reflects a principled understanding of the topic rather than a simple telling of what they have personally learned. In other words, she is encouraging talk which requires transformation of their personal knowledge rather than merely knowledge-telling (Bereiter & Scardamalia, 1985).

In such sequences, the teacher uses her follow-up moves to model this complex but powerful thinking skill; that is, she takes the child's contribution and, in her response to it, demonstrates how one can extrapolate from a range of specific experiences a principle which applies to those past experiences and possibly to similar future ones as well. An obvious example of this occurs in turn 4, where Tema's observation is utilized to form the basis for the introduction of the scientific "thematic formation" (Lemke, 1990) "x is a form of y."

In the next sequence, Auritro, the fourth child to offer a personal response to the original question, not only picks up on the teacher's intervening amplification of time as a form of measurement, but extends it by tacitly juxtaposing standard and nonstandard methods of measurement. Counting belongs to the latter class, which "isn't always accurate" (7). Comparing Auritro's contribution to those of the preceding three children, it is clear that he is expressing an idea that has wider application and one which evidences an ability to extrapolate and articulate a principled understanding from particular physical experiences. To provide a bedrock of such experiences is, in fact, one of the teacher's priorities, as she believes that it is a necessary basis for engaging the children in talk which has the potential for knowledge transformation. In Auritro's case, he and a few other children had chosen to investigate the use of nonstandard methods of measuring time, such as counting, clapping, and pouring an agreed amount of water out of a pop bottle, in order to measure the duration of activities such as walking from one end of the hallway to the other. In so doing, they had confronted the issue of these methods' reliability.

In her follow-up to Auritro's introduction of the topic of accuracy of measurement, the teacher makes explicit Auritro's tacit comparison by reposing it in the form of a question: "what is more accurate than counting?" (8). This question enables those children who have investigated time by using standard measurements, or those who constructed devices such as a salt timer, to bring in their expertise. Thus, the topic is extended both in "depth and breadth," as the teacher put it, and the children are provoked to think beyond the local level or the single case as they draw upon their collective experiences to arrive at understandings which will have wider and future applications. Following the request for specific examples (10), the next 20 turns are spent in recalling the various devices that different children had experimented with.

Then, in turn 31, the teacher poses a question which is in some ways the obverse of the one asked earlier: "Of all that you have done ... which are the ones that are the least accurate as a kind of . timing device?" Her intention here is to invite the children to go beyond the devices themselves to a consideration of their relative accuracy. Then, in the following sequence, as she follows up their suggestions with a request for a justification (33), a new issue is brought into the discussion.

33 Teacher: Counting or stamping your feet and using your heart-beat or walking round the room . that is the least accurate Why? Why is it least accurate?

34 Bianca: If you < use > your heart-beat sometimes your heart-beat gets faster, like fai- um- like you've like- you've been- you've got um so many- like a lot of energy and then <you're trained> to get your heart-beat and then because you've got a lot of energy you feel like running around, and then you start running around your heartbeat's going to get faster < so it changes >

35 Teacher: And I think er Bianca is bringing things to another part of this science unit <that you have learned about > . "the processes of science" (writing on board)

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Once again, it is a child's contribution that provides an entry to the new topic. For although, in itself, Bianca's answer is largely anecdotal in intention, the teacher recognizes in it an opportunity to bring into the discussion a fundamental principle to be observed in carrying out experiments, and one that the children have encountered in several of the earlier activities. In her follow-up move, the teacher makes this connection (attributing it to Bianca) and announces this new topic, writing it on the board to underline its importance, "The Processes of Science." Then, following the lead provided by Bianca's reference to the variability of the heart-beat as a measure, she reminds the children of how they have talked about the need to control the variables in an experiment and, in turn 40, she poses the question: "Why must we control our variables?"

The first answer she receives shows that Tema has at least a partial understanding of what is at issue and so, to signal this, the teacher repeats the keyword "accurate" in the follow-up move. However, since this is not a fully adequate answer, she asks a probe question to elicit an alternative within the frame that Tema and she have jointly provided: "if we don't control our variables, x is not accurate." This is obviously a difficult question for 8year-olds to answer in that form. However, Bianca finds an alternative, but appropriate, solution by repeating a phrase that has been used on a number of previous occasions: "It's not a fair test" (43).

40 Teacher: OK. why must we control our variables?
41 Tema: Because ifwe don't, the time won't be accurate and so you won't get the correct timing
42 Teacher: Not so much the time is not accurate, what is not accurate?
43 Bianca: It's not a fair test

The Principle of "A Fair Test"

The problem of how to make sure that their experiments were "fair tests" had been introduced in the very first activity of the unit. Some had chosen to try to construct a salt timer that would measure exactly 30 seconds. Emily, Veronica and Lily had chosen to invent a way of measuring how long it took to empty a bottle of water. In a conference with their teacher when they had gathered their materials, the teacher had presented them with two problems to solve: the first was to invent a method of measuring how long the emptying took, and the second was "to make sure your test is fair." To help them understand what was meant by a fair test, she had discussed a number of possible variables with them:

Teacher: The meaning of "fair test" is if you empty a bottle-say if you fill the bottle half. and Veronica fills her bottle full. would it be a fair test?
Veronica: No
Emily: No . you have to- if I filled my bottle half and to make that a fair test she would fill her bottle half
Teacher: That's right. and what about Lily's bottle?
Emily: She would fill her bottle half- half
Teacher: So all your three bottles must have the same amount of water

Now how do you ensure the same amount of water?

Emily: Well.

Teacher: Do you just estimate?

E and V: No

A few minutes later, after they had considered possible solutions to these problems, the children returned to their corner of the classroom and carried out the first trial, clapping plastic cups together to mark the beat and counting the number of claps that were made before the bottle was completely emptied. In the first trial, Lily's bottle was only half full, so the trial was aborted and they returned to the bucket to fill all their identical FiveAlive bottles "to the brim." Then they took it in turns to empty their bottles, with one child clapping and the third counting the number of claps. Lily, who went first, took four claps. Emily and Veronica each emptied theirs in a count of three. Emily, who has assumed the role of group leader, pauses for a moment's reflection:

Emily: I know, me and Veronica are tied . Do you know why you were slow? (to Lily)

When Lily does not answer, she puts the question again in a different form:

Emily: What we did . what we did was we . did a method by timing Now, d'you guys think it was a fair match?

Veronica: Yeh

Emily: Do you? (doubtfully)

Veronica: Cos we each used the same . <thing>

At this point, Emily goes to fetch their science logs so that they can record their results. But the problem of the discrepant results is obviously still bothering her for, when they have finished writing, she returns to it again.

Emily: I want to ask you some questions before we do something
Why do you think it was a fair match?

Veronica: Cos the bottles were filled to the exact same amount . because exactly the same *

Emily: Yeah, like we counted EXACTLY. * Yeh like I ****
Now . why d'you think . she lost? (referring to Lily) Why?

Veronica: Cos she was-

Emily: Probably she poured it- probably she poured it slow

Veronica: Like she goes like this (demonstrating) and then she-

While Veronica is speaking, the teacher joins the group to find out how they are getting on. Emily and Veronica describe what they have been doing, ending with a summary of their recent conversation. The teacher's follow-up question prompts Emily into a statement that recognizes that, for the test to be fair, the angle of pouring must also be controlled.

Teacher: OK, so you- so that is a good observation- you observed . that Lily's count . was more . than both of you . and you figure that it's because of the way she poured it. Now, how can you make sure . that it's a fair test between all three of you?

Emily: Well. a fair test- well I don't really think it's fair now because . it was fair we put it the same size of the cup by the measuring cup, but I don't think it was fair because we poured it- we turned it right over . and Lily just poured it like this, kind of so I don't think it was fair . (T: Uh-huh) I- I think that's why she um- . was slow

Writing in her log book later, Emily included the following observation:

> "Test 1 It wasn't a fair match because Lily tilted her bottle sideways. Our method was claping."
>
> and for the activity as a whole:
>
> "What I learn I learned that if the bottle has a small mouth the water will come out slower than a wide mouth bottle."

From the episode that we have just summarized, it seems clear that Emily, at least, has developed some understanding of the principle of a fair test and, as leader of the group, she has also drawn the other two girls into using this principle in the consideration of their results. However, it is worth noting that, in her original posing of the question to her friends, she uses the expression "a fair match." In taking over the teacher's concept, it seems, she has assimilated it to her own concept of a competition and, as a result, she has recast the results of their first trial in terms of Lily having "lost."

There are various ways in which this might be viewed: as an indication of a discrepancy between Emily's understanding of the principle and the more conventional interpretation; as evidence of the connections she has made between a new idea and a domain which is both familiar and significant to her; or as a novel application of the principle of a fair test. All of these would, we think, be valid interpretations. But what seems most important to us about this episode is the clear evidence it provides for the way in which the children are actively making sense of what they observed in the trial, using the concept of "a fair test" as a tool to help them do so, and gaining a greater understanding in the process.

In fact, in the next activity, in which the children had experimented to discover which variables affected a pendulum's period of swing, there was further opportunity to appreciate the importance of changing only one variable at a time in order to ensure that the test was fair.
It is to a collaborative reconstruction of the different groups' experiences with pendulums that the teacher now turns in the review discussion.

44 Teacher: Remember when you did the pendulum, when one group did the bob . changing the weight of the bob, one group changing the type of bob, one group changing the release height. and all of us did changing the length . that- what- when you want to change the release height what was constant? What was the variable we held constant?

Emily's group, which on this occasion also included Bianca and Jamilla, had tested the effect of changing the weight of the bob. Over a period of some 30 minutes, they had systematically added one washer at a time to their string pendulum and timed the number of complete swings in 30 seconds. The following extract captures something of the quality of their engagement in the task. Lily has just added the fourth washer and Emily, who is responsible for timing each trial with the stopwatch, prepares to start.

Emily: OK, ready?

Bianca: No .. we've got to measure it to forty-four [B takes the tape-measure and, while V holds the pendulum horizontally, she measures its length]

Veronica: Forty-four?

Bianca: Yes

Emily: On your marks .. get set, go!

ALL: One, two, three .... (continue counting)
[Veronica sways from side to side with the pendulum, making as if to push it on each swing] .. nineteen, twenty, twenty-one
Emily: Stop!

B and V: Twenty-one (laughing)

Jamilla: [entering the results after each trial]

Emily: Five (instructing them to make the bob up to 5 washers)

While Lily is adding the next washer, Emily has nothing to do and she idly swings the stopwatch by its carrying strap. As she is watching it swing, she suddenly sees the significance of what she is doing and announces: "I've got a pendulum." Jamilla immediately picks this up and starts to swing the kiss-curl on her forehead, announcing that she too has a pendulum. She is followed by Bianca, who swings her ponytail as a pendulum, and finally by Veronica who, not to be outdone, shakes her whole head to make her loose hair swing as a pendulum. They all laugh with pleasure at the discovery of this extension of their understanding of what may function as a pendulum.
By now, the extra washer has been added and Emily is keen to proceed. But there is a problem. The knot is not secure.

Veronica: No wait

Lily: Uh-oh . that not way to tie it on

Veronica: I started to hold them and they ***

Bianca: I'm wonderful at tying knots, I love them I mean I like tying them

While Bianca is retying the knot, the teacher approaches to check on how they are progressing.

Teacher: What did you get, guys?

Bianca: We got a pattern of twenty-two, twenty-two. twenty-one, twenty-one

Jamilla: Twenty-two. twenty-one. twenty-one

Bianca: We want to see what it's going to be this time

Emily: I predict the more washers there, the less * swing

Bianca: I think this time maybe we'll get something like nineteen, eighteen or twenty . something like that

Jamilla: Maybe

Bianca: Maybe

Emily: I predict twenty dead . bet you have twenty

As the teacher walks away, they prepare to start the next trial. But first Bianca insists that they must measure the string to make sure that it is still the right length. As she does so, she notices that, with all the tying and untying, the string is fraying.

Bianca: Cos it's actually.. it's actually the string that's breaking. see

Veronica: Yeah, it's the string

Bianca: So what we have to do is- the string's probably getting shorter by the minute

Emily: I don't get it

Bianca: Because it's breaking, you know these things are getting heavy on the string and if they're all unpleating . next thing you know it'll be tearing off

Finally, however, the knot is firmly tied, the length of the pendulum checked, and the trial completed. The result is as before: twenty-one swings. After considerable further discussion, they decide that changing the weight of the bob does not systematically affect the period of swing. This is captured in the following extracts from Emily's journal. The first entry was written before she carried out this activity:

> My Observation
> I found out that the longer the string is, the less swings. The shorter the string is, the more swings. I think I know why! Because if you have a long string you can make it sway more. If you sway it more it will take longer to sway so it will have less swings. But if you have a short string it will go fast because it cannot sway so much. Probably it isalso the wight.

This second entry was written when the group had finished the trials involving changing the weight:

> My Observation
> I learned that adding more washers make no difference. Not even the count of swings. I thought it would put more wight on the string so it will go slower each time. Our score was all 21.

When it is their turn to report, then, there is a wealth of shared experience within the group on which to draw. However, for Veronica, who is chosen to speak for the group, it is still a difficult task to express what she knows in a form that is explicit enough for others to understand. Nevertheless, with prompting questions from the teacher and contributions from other members of the group, a satisfactory account is constructed. Finally, after the last group has reported in similar vein, the teacher invites the whole class to join with her in drawing a conclusion about the principle's more general applicability:

72	Teacher:	So that is an example of what we mean by "a fair test" ... it's very important in science . Those are some of the science processes you have to think about. OK?

"What Time is it in Scotland?"

At this point, we want to move on more rapidly to an episode that occurred some 10 minutes later. In the interim, the group had reviewed the designing and making of water timers and rolling ball timers as further instances of the "science processes you have to think about" (72). Then the teacher had reopened the more general discussion of what they had learned about time and, on the basis of Tema's contribution—

91 Tema: I learned that time may not only be in seconds, you may, see it as a minute, a second-and a second is made up of . quite a few fast counts

she had spent a few minutes in checking that the children knew the constituency relations among seconds, minutes, hours, days, weeks, months and years. Next followed another opportunity for students to talk about what they had learned, which the teacher followed with an episode of more direct teaching about the basis for the different units of time in the movement of the earth on its axis, and in its orbit around the sun. This latter topic was also developed dialogically, but interspersed with longer turns by the teacher, in which she accompanied her explanation with demonstration, using two of the balls from the rolling ball timer to represent the earth and the sun.

The episode to be examined next followed directly from the one just described, and was originated by Bianca. In a pause that occurred while two children were going to fetch the globe, she raised her hand to indicate that she had a contribution to make.

204 Teacher: Yes . while somebody's doing it (= fetching the globe), Bianca you have a question?

205 Bianca: Well, um, you know last night I was going to bed something like quarter to ten- I can't exactly remember but um my sister said that um- I asked her um "guess how lo- guess what time it is in Scotland" (Bianca has recently arrived in Toronto from Scotland) and she goes "I think it's um about ten o'clock" and I go "But it's only ten o'clock here it can't be ten o'clock over

there" (T: Mm) . so I counted back five for the time difference and I said "It's actually four thirty um in the afternoon and they're just about to have their cookies"

206 Teacher: Very good . Now Bianca's bringing up another point

Given the point at which she makes this contribution, it is likely that Bianca has already made the connection between the time differences between different countries and the rotation of the earth in relation to the sun. However, because other children may not have followed this implicit connection, the teacher makes it explicit by relating the anecdote to her previous explanation and by once again demonstrating the two movements of the earth, this time using the globe to represent the earth and Angeline, who is sitting at one end of the semicircle of children, to represent the sun. Then, against this general background, she goes on to consider Bianca's example in detail, correcting, in passing, the error that Bianca had made in carrying out the rather difficult operations involved in calculating the time difference between the two countries.

Although the teacher had not embarked on the discussion with a preplanned agenda of her own, the topic of time zones would obviously have been a candidate item for inclusion on such a list. Therefore, when Bianca presents an opportunity to bring it into the discussion, the teacher is pleased to take it up. Once again, what the teacher later described as "a teachable moment," has arisen. This is made particularly clear in her focusing move, "Now, Bianca's bringing up another point" (206), in which she deftly accomplishes two purposes, first, that of authorizing the relevance of Bianca's anecdote and, second, that of signaling that the topic is one of general importance, that merits further discussion. In fact, this topic is pursued for the remainder of the lesson, as it is one that is of personal significance to many of the children.

Drawing on anecdotes similar to Bianca's, contributed by children with relatives in Hong Kong, the Philippines and other countries, the teacher is able to help the children to attach real-life significance to the concept of time zones, and the differences in time between them, which might otherwise have been too abstract for them to grasp. One of these anecdotes, in particular, is worth quoting in full.

The class contains quite a number of Chinese Canadian children, and Emily, whose family comes from Hong Kong, has just been recounting a conversation with her father about the time difference between Hong Kong and Toronto:

258 Emily: ...say it was nine o'clock and I asked Dad "What's it like in Hong Kong now?"
and he said "It's- it's the same time but it's the morning, nine o'clock in the
morning"

As the teacher recaps and makes the connection with Bianca's example, Lily, another Chinese Canadian girl, raises her hand. As the teacher immediately recognizes, this is an important moment. Lily has only been living in Canada for justover a year, and is usually very reticent about speaking in front of the whole class. On this occasion, however, she clearly feels her story is sufficiently important for her to request an opportunity to tell it.

266 Teacher: ...that's why your Dad says Hong Kong to here is a twelve hour
difference, that's exactly . half way round for time whereas . Scotland
to here is five hours difference
Yes, Lily
267 Lily: When I was in China . my Mum always called me at the night and er-
and I- I don't like- I don't er I don't want to wake up and my- my
Grandmother say “You have to wake up, your mother on- in the phone."
So I have to listen to him
268 Teacher: That's right . she says- Lily says that when she was in China . where's
China? you show me (to Lily) [Lily points to the position of China on
the globe]
269 Auritro: Er you just-
270 Teacher: There, China's over here . (pointing) and her Mum was in . <u>Canada</u>
271 Lily: <u>Canada</u>
272 Teacher: -her Mum called at say two o'clock in the afternoon, say now, cos the
sun is there two o'clock I would say it's roughly here . is she still
asleep?

273 Children: Yeh

274 Bianca: Two in the morning, **

275 Teacher: Now, it's really not as much as Hong Kong, * slightly less, but she's still asleep . so that's why she was telling us her grandmother said "Your mum is on the phone, get up! Your Mum is calling you"- which means phoning for you and she says "Why does she phone me at night?" But is it night for your Mum?

276 Lily: <u>No</u>

277 Children: <u>No</u>

278 Teacher: No, it's daytime . and say if Lily comes over- the earth moves here and it's daytime (i. e. in China) and Lily calls her Mum . Lily phones her Mum, would her Mum be awake or asleep?

279 Children: (laugh) Asleep

280 Teacher: See now why? do you see it now with the globe and the sun

281 Children: Yes

As in learning their first language, what prompts children to take risks in using the linguistic resources they are learning in a second language is so often the combination of having something they feel it is important to say and an audience who will be interested to hear it. This is what happens here. As with other children's contributions, the teacher picks up Lily's anecdote and retells it to give it added effect, using it at the same time as a particular case of the more general principle that is under discussion. Whilst illustrating the rich resource for developing understanding that is to be found in multicultural classrooms such as this, this episode also exemplifies very clearly just what is meant by the co-construction of meaning.

LEARNING FROM THE PAST: LEARNING FOR THE FUTURE

In the introductory section of this chapter, we outlined a way of thinking about education in which teaching was characterized as the provision of opportunities for learners to appropriate the achievements of past generations— as these are embodied in cultural tools and their associated practices — and to transform them into a personal resource for individual thinking and problem solving, now and in the future. This discussion, we want to suggest, is an excellent exemplification of this process in action.

In order to justify this claim, we should like to revisit the section of the discussion concerned with "the processes of science," in order to consider it from this point of view. The principle of "a fair test" is just such an intellectual artifact— or tool— and one which is of central importance for the way in which scientific understanding is advanced in our culture. Indeed, it is so central that it is easy to ignore its artifactual nature. Yet this principle, which is taken for granted as necessary in any experimental attempt to understand relationships of cause and effect in the material world, was developed in the course of practical activity by our forebears over many generations in the past. That it is a tool that has to be learned in action was made very clear in the course of the activities in which the children engaged and in the accompanying discourse.

We have already seen how Emily and her friends grappled with the problem, as they reflected on the probable reason for Lily "losing the match." Now we want to consider the experience of Auritro and his group as they tested the effect of changing the type of bob on their pendulum and in the subsequent discussions.

In the class discussion which was held at the end of the experimental work on pendulums, it was finally agreed that it was only changing the length of the pendulum that changed its rate of swing, and a rhyming slogan was coined to make this finding memorable: "The longer the string, the slower the swing." However, earlier in this session, when the groups described what they had done and reported their results, Auritro's group had reported results that were anything but conclusive. The problem, it transpired, was that, in changing the type of bob, they had been unsuccessful in keeping the length of the had followed the cultural practice associated with the use of this principle, the teacher is helping the children to take over the practice, together with the understanding that it embodies, as a tool that they can use in all future scientific experiments.

Overall, then, one of the teacher's intentions for this discussion was that the children should draw on their various group experiences of practical work and on other relevant information to construct a shared understanding. But she also intended that their understanding would be informed by the publicly accepted account of the phenomena that they had been investigating. The children were certainly willing and able to play their part: following the initial "macro" question asking what they had learned, they eagerly offered a wide range of important topics for discussion (cf. Table 1). However, as might be expected of children of this age, these are largely in the form of observations and anecdotes drawn from personal experience. Therefore, in order to create what Edwards and Mercer (1987) refer to as culturally appropriate "common knowledge," a considerable amount of "follow-up" work was required on the part of the teacher. On each topic, this was achieved, first, by eliciting similar observations and recollections from other members of the group so that, together, their contributions might build into a shared account and then, by extending and reinterpreting their contributions, drawing on the linguistic register that is more generally used to talk about the related activity in the culture. In this way, while encouraging and valuing the ideas and experiences that the children were keen to contribute, the teacher, as "an authoritative representative of the educated culture" (Edwards & Mercer, 1989, p. 97), provided an opportunity for the children to take over and internalize her organizing cognitive structures and associated language so that, in the future, they would be able to deploy these resources when engaging in further activities for which they were relevant.

LEARNING ABOUT TIME: THROUGH THE CHILDREN'S EYES

The emphasis in the paper so far has been on an exploration of what the children had learned from their study of time, as seen through the lens of the collaborative meaning making that occurred in the final discussion. However, as will be clear by now, this discussion was itself an occasion of learning, as important as any of the activities that were reviewed during its course. For, as well as clarifying and extending the science concepts associated with those activities, the discourse that the teacher and children co-constructed itself provided a model, on the intermental plane of public discourse, for the intramental dialogue of inner speech in which individual thinking and problem solving is conducted.

In *Thinking and Speech*, Vygotsky (1987) hypothesized a developmental progression in the learning of any aspect of cultural knowledge, from adult-assisted interpersonal interaction, through similar interaction with peers, to a stage where the individual is able to function autonomously under the control of the discourse structures internalized from social interaction. In this section, we shall look again at what the children were learning, focusing here on how they were appropriating the concepts and processes of science as evidenced in their talk and writing.

One very clear example of this developmental process in action was seen in the episode quoted earlier, in which Emily initiated a review of the results of the bottle-emptying task. Attempting to explain to herself and her friends why Lily had taken longer than Veronica and herself to empty her bottle, she drew upon her interpretation of the language that she had just recently encountered in the conference with the teacher and couched her questions in terms of "a fair match," in which Lily "lost." Interestingly, Emily's conflation of "a fair test" with a fairly conducted competition came into play again in the final practical activity, when she and her group designed and made their own water clock. However, they were not content to make just one; at Emily's suggestion, they decided to make two identical water clocks so that, in addition to making sure that their experiment constituted "a fair test," they could also have races between them. Two years later, on the other hand, her understanding had changed. In an interview at the end of her grade five year, she was asked about things she had learned that it was important to do when "doing science." Without hesitation she replied: “I think you have to be . um . consistent and do fair tests for everything.” And when asked what she understood by "a fair test," she replied: “You have to keep everything the same and if you change a thing you have to change it all.”

In the intervening years, Emily had continued in the same classroom with the same teacher and many of the same children. During that time many other science topics had been investigated, always with opportunity for practical work and often involving experiments. Certainly the issue of fair tests had been discussed on more than one occasion and, from taking part in these activities and discussions, Emily's understanding had gradually been transformed until it approximated more closely the conventional version. Here, the value of collecting longitudinal data is particularly clear, for it allows us to see that, as Vygotsky (1987) pointed out, concepts are not learned instantaneously in their mature form, but are appropriated and modified over numerous occasions of use in settings in which they are relevant to the task in hand.

A second feature of Emily's discussion with her peers that is worth commenting on is its reflective nature. This stance was almost certainly taken over from the review discussions with which the teacher ended most activities, and from her repeated injunctions to the children to use the writing of entries in their science logs to reflect on what they had learned. We have already quoted Auritro's log entry, in which he tried to explain to himself why his group's testing of different types of bob had been unsuccessful. Here is another reflective entry that attempts to draw conclusions from a series of experiments involving pendulums. It was written by Jamilla, who had been the record keeper for the group that tested changing the weight of the bob. After each child had made a pendulum with a washer and a randomly cut length of string and counted the number of swings it completed in 30 seconds, the pendulums were arranged on a chart in the order of the number of swings completed by each pendulum. From the resulting display, it was clearly apparent that "the longer the string, the slower the swing." Jamilla wrote:

> I noticed that when we made a chart, the person who had the longest string
> had the smallest amount of counts.
> Why? I think it was the length of which the string was.
> Why? The release height does not matter, and the weight of the bob does not matter.
> Why? Bianca, Veronica, Emily, and I did a test on weight of the bob.
> Other groups did tests and it did not matter.
> Only the length matters because it takes a longer or shorter time.

In all these entries, it is a personal observation or discovery that provides the point of departure and the writing serves not only to communicate that information but also acts as a "tool" with which to make sense of its significance. Not all the children were able to make such sophisticated use of their writing, of course, and some relied more on pictures and diagrams than on written text. The teacher deliberately encouraged such "picture writing" by those children for whom the writing of text was a painful struggle. This was because she was more concerned that every child should experience the value of recording and reflecting than that they should produce conventional text.

For example, Lily, the newly-arrived Chinese girl, put considerable effort into drawing and labeling the materials that her group had used in constructing a timer that would measure 30 seconds, based on the design of an hour-glass, but using salt instead of sand. Nevertheless, despite her limited command of English, she also wrote the following account of what, for her, was either the most memorable aspect of the experiment or the aspect that she felt most able to write about. In any event, she succeeds in giving a graphic account of how the teacher helped them to solve the "parbom" (problem) they encountered in trying to make the right-sized aperture in the paper diaphragm between the two pop bottles that, taped together, formed the two parts of the "hour-glass."

> Emily Veronica and I try to maked good but every time we do tat we has a little parbom, first time the hole is very bag only 7 secon and tn we try to do it slowly so Emily pat in sum salt and this time we taked 25 sicon and the last time we do that Emily pat in sum salt and only 27 and Mrs X. was come in and she tell us how to do it she take a bag funnel a madm funnel and a little funnel and she sad the bag one is father the madm one is mom and the little one is baby. So Mrs X take the baby and count to 30 and she take the mom the mom is 20 agn Mrs X take the father the father is 14 now Mrs X and us know the baby is the roret one so we copy the hole forkm baby funnel wnet we finisht we trn this time we got 30.

> [Emily, Veronica and I try to make it good but every time we do that we have a little problem. First time the hole is very big [and it took] only 7 seconds, and then we try to do it slowly so Emily put in some salt and this time we took 25 seconds, and the last time we do that Emily put in some salt and [it took] only 27. And Mrs X came and she tell us how to do it. She take a big funnel, a medium funnel and a little funnel and she said the big one is father, the medium one is mom and the little one is baby. So Mrs X take the baby and count to 30 and she take the mom, the mom is 20. [Then] Mrs X take the father, the father is 14. Now Mrs X and us know the baby is the correct one so we copy the hole from baby funnel. When we finished we try. This time we got 30.]

Even at the age of eight or nine, then, many of the children in this class were capable of reflecting, in speech and writing, on what they were doing, and were able to understand the relationship between the "hands-on" practical work, which they enjoyed so much, and the "minds-on" spoken and written discourse in which they planned and reflected on what they were doing and learning. Through these interrelated activities, carried out jointly with their peers and with their teacher, they were taking over the knowledge and artifacts of previous generations and using them to make and communicate their own sense of the puzzles and problems they encountered in the present.

At the end of the year— some months after the end of the unit on time— we interviewed two groups, one of boys and the other of girls, to ask, once more, "what have you learned?" The answers they gave confirmed our expectations. Although none of those interviewed recalled the episode with the malfunctioning water clock, with which we introduced this chapter, they did remember many of the activities they had carried out, and they referred to their logbooks to make sure they got the details right. Asked which they considered most important— practical activities, reading, writing or talking— the girls responded as follows:

Veronica: I think the writing
Bianca: All of them
Emily: Yeh all of them, but I think one thing um very important is that we all discussed about it, like talked
Veronica: What I think is because um you need to write for er- and you need to read to get the idea and then you need to talk to get the- er talk to the other person to get the idea of what you're going to do and who's going to do what so that you don't get into a big fight when you're doing it
Bianca: Yeh and I think the fun activities are important cos you can also have some fun doing your science and the writing's good because it builds up your * and your language your brain and also discussing about it it builds up your confidence to talk about things and also your- er your language skills and things

like that and I also think the reading's very good because in most jobs you do have to know how to read and to write

Jamilla: You also learn about math sort of because you're doing um-. science is a lot of patterns and things like that and math is also patterns and things like that so you get a lot of everything just by doing science

Emily: And you learn a LOT

Asked the same questions, the boys gave very similar answers. They, too, had enjoyed the practical activities and could recall many of them in considerable detail. Auritro and Benjamin, for example, explained very clearly why their salt timer had taken longer to run through in one direction than in the other. The problem, they were convinced, was that, in piercing the hole in the paper diaphragm, they had created the equivalent of a valve: the pierced paper opened up to let the salt pass through easily in one direction but, when the timer was inverted, the weight of the salt tended to push the paper back into its original, unpierced position, thereby slowing down the rate at which the salt passed through. However, because this reasoning took place only after the pop bottles had been securely taped together, they had not had the opportunity to empirically verify their hypothesized explanation.

The boys also recognized the value of the reading and writing. In fact, they tended to place more emphasis on reading than the girls had done. But reading, writing, and talking were all seen as complementary activities which, when carried out in a collaborative group, enabled real progress to be made in the construction of group and individual knowledge. This is how Auritro put it:

> If you know something that- you know something that somebody else doesn't know, somebody else knows something that you don't know, then you can add those ideas together

And, on the role of reading and writing, the group had this to say:

Auritro: You read the- once you do the science experiment, you experiment about it, then if there's a book about that animal- that creature, you could read about it and then you could write about it and you could make a whole new thing of it.

Benjamin: And you can er like if there is a book on flower- on a flower- certain kind of flower and you're um you're experimenting with it you can mix the breeds and then like- and then write er write down what you've experimented with .

Steven: After you've finished an experiment you should always write it up in the science log. Because if you want to do that experiment again you might forget how to do it

Teacher: So that's one good reason for writing, so that you have a record of what you've done. Are there any other reasons you can think of for writing?

Steven: Writing books to help others to understand

Auritro: Yeh, understand the **

Teacher: You mean you write to help other people understand or you write to help yourself understand?

Auritro and Steven: Both

Auritro: You help yourself by reading and then you write it down so other people can understand

Steven: Well wouldn't that be copying the book?

Auritro: No .. you have to read from a book because once . you read the book and you know- and you know a little bit and you read the book and you get a little bit more. You can write your own book, some more, and then you could ike publish it and then give it to a science fair and then people could read it. If you know something little, and that book doesn't have it in there, you could add it up together and then you get another book.

Auritro, it appears, already has a well-developed, if intuitive, understanding of the intertextual nature of reading and writing and of the way in which knowledge is collaboratively and progressively constructed through reading, writing, and talking.

Conclusion

In presenting an analysis of the review discussion with which the unit culminated and of some of the activities on which it was based, we have tried to show how learning in science— or in any other curricular area— can be seen as part of a continuing cultural process of appropriating the achievements of the past and transforming them into a resource for creative and innovative problem solving in the present and future. In the episodes selected from the discussion, we have seen how the experiences of the immediately preceding few weeks were collaboratively reviewed and their meaning reinterpreted in terms of principles and practices that previous generations had invented to make sense of the phenomena in question.

Similar discussions had also occurred in relation to the various activities in which the children had engaged throughout the unit; however, this one had particular importance in that it was used as an occasion for making connections among these individual topics in order to achieve a more integrated understanding of the theme of time. Such opportunities to synthesize and reflect on what has been learned occur all too rarely under the pressure that many teachers feel to hurry on in order to cover the recommended curriculum. Yet they constitute an essential element of any curricular unit, if school learning is to be more than the accumulation and memorization of isolated bits of information (Wells, 1995).

But it has also been one of our aims to show how, in appropriating the knowledge and artifacts from the past, children use them for their own purposes and put their own stamp upon them. The episode in the review discussion in which the basis for the different time zones is explored provides a clear example of the former. For Lily, who has rarely spoken in the whole class group, the new understanding she has achieved of the personal experience of being phoned by her mother in the middle of the night is significant enough for her to break her silence with a brief story that enables her to become a fully participating member of the classroom community. In a different vein, Emily's personal interpretation of a fair test as involving competition ("a fair match") is an example of the latter. But perhaps more significant than either of these rather specific examples is the tenor of the discussion as a whole, with its numerous examples of the children's ability to infuse general concepts with their own personal and particular meanings and at the same time to reframe those personal meanings in more public terms that make them relevant and, therefore, worthy of sharing.

A second theme of the chapter has been the dual role of discourse in the learning and teaching of science. On the one hand, "doing science" is to a considerable degree a matter of participating in the various discourses by means of which the scientific community addresses the problems of current concern and creates and debates novel solutions that have the possibility of transforming and extending previous knowledge; therefore, one of the major goals of the science curriculum must be to enable students to gain sufficient control of these specialist discourses to be able to use them in constructing their own knowledge. On the other hand, as we have seen, it is also in the ongoing discourse of the classroom that the teacher and students create the forum for co-constructing the meanings in terms of which they make their own sense of these specialist discourses and of the situations to which they apply.

The same arguments could be made for the other subjects in the school curriculum. In all areas, one of the major goals of education is for students to appropriate the modes of discourse that are specific to the different discipline-based ways of doing and knowing so that they are able to take part in those practices and, in so doing, to make them part of their own resources which they can use for their own purposes. At the same time, it is in the more familiar patterns of classroom discourse with their peers and teachers that students are enabled to build bridges between these specialist discourses and those with which they are familiar from their experiences at home and in the larger community. It is, therefore, in providing them with opportunities for apprenticeship into the discourses of the disciplines, we believe, that teachers will most fully achieve the aims that are captured in the phrase "language across the curriculum" (Wells, 1994).

Despite the theme of the volume in which this chapter occurs, as may have been noticed, we have not singled out literacy for special attention. This is because, like the children, we see it as an integral component of any unit of study. To do science— or history, or mathematics— is necessarily to engage in reading and writing, along with doing and talking— in order to formulate and address the problems and issues that seem worthy of sustained attention with respect to the topic under investigation. As we argued earlier, language and literacy are cultural tools for thinking, feeling, and communicating with. Like other tools, they are best mastered, not through decontextualized exercises, but through appropriate use in situations of significance to the user. This chapter started with an account of just such a situation, in which the real problem posed by the malfunctioning water clock led to a creative solution which required the integration and application of a variety of cultural tools, including logical reasoning, reading of the junior science guide, and talk for coordinating joint activity. In this situation, perhaps more than in any other we have described, the children really showed what they had learned.

We should, therefore, like to end this chapter by quoting Emily's insightful conclusions about the year's work. In the end-of-year discussion referred to above, the children were asked how they, if they were responsible, would plan the work for the next year's students. Here is Emily's reply:

> We should give the children— the grade threes that came— to go through the "Innovations" [the resource book they had used]* and then I would ask them questions, like what we did or what we remember, like "What is science?" "What did I think of it?" and I would I think I would start them by um giving- start with projects- not projects but making things, and then I think I would um- few days later I would gather them on the carpet and they all share what they observed and then see they'll become like us, just writing them in our books...

* *Innovations in Science.* (1991). Toronto, Ont: Holt, Rinehart & Winston.

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