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ABSTRACT

This conference presentation describes how students develop the cognitive processes through which they acquire knowledge from their classroom experiences. The data were taken from five studies of individual students' classroom experience and its relationship to the learning of curriculum content in typical science and social studies units in the upper elementary school. Data on classroom experience were obtained from simultaneous video-recordings, audio-recordings with individual microphones, and continuous observation of selected students. Data on student learning came from tests and interviews conducted before and after each unit and 12 months later. The resulting model of knowledge acquisition, which predicted with 80 percent success exactly which curriculum concepts and propositions each student learned and remembered 12 months later is described. The conditions of knowledge acquisition and the role of working memory in the sorting and organizing of experience are described. The paper then develops a theory of internalization from the work of Piaget, Vygotsky, and others, and examples of the classroom experiences of students are used to describe how students participate simultaneously in the public, semi-private, and private worlds of the classroom. Evidence for the private world is taken from individually recorded self-talk. Five activities/processes that are involved in acquiring knowledge from classroom experience are described both as simultaneously private processes and social activities. The transactional relationship between the enactment of these processes in the public, semi-private, and private worlds of students' experience provides the conditions for their internalization. Contains 59 references. (Author/KB)

Learning how to learn

The social construction of knowledge acquisition in the classroom

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ABSTRACT

This article describes how students develop those cognitive processes by which they acquire knowledge from their classroom experiences. The data comes from five studies of individual students' classroom experience and its relationship to the learning of curriculum content in typical science and social studies units in the upper elementary school. Data on classroom experience was obtained from simultaneous videorecordings, audiorecordings (individual microphones), and continuous observation of selected students. Data on student learning came from tests and interviews conducted before and after each unit, and 12 months later. A model of knowledge acquisition is described that predicted with 80% success exactly which curriculum concepts and proposition each student learned and remembered 12 months later. The conditions of knowledge acquisition, and the role of working memory in the sorting and organising of experience, are described. A theory of internalisation is developed from the work of Piaget, Vygotsky, and others, and examples of the classroom experiences of students are used to describe how students participate simultaneously in the public (teacher-student), semi-private (student-student), and private (in-the-head) worlds of the classroom. Evidence for the private (in-the-head) world is taken from individually recorded self-talk. Finally, the five activities/processes that are involved in the acquisition of knowledge from classroom experience are described both as simultaneously private processes and social activities. The transactional relationship that exists between the enactment of these processes in the public, semi-private and private worlds of students' experience provides the conditions for their internalisation.

Teaching is an art. It is perhaps the most enduring and pervasive of all creative endeavours. However, like all highly developed art, it depends for its success on a background of well-established expert knowledge. In the case of teaching, this background knowledge must be about how the minds of students are influenced and shaped by educational experiences. The purpose of this article is to advance this expert knowledge by describing how students acquire those cognitive processes by which they acquire knowledge. In other words, to describe how students learn how to learn. In previous articles in this and other journals (Alton-Lee, Nuthall, & Patrick, 1993; Nuthall & Alton-Lee, 1992, 1993), we have described how students experience classroom activities and reported a model of how knowledge acquisition occurs in typical science and social studies units in upper elementary and middle school classes. This model was based on an analysis of detailed observations and recordings of individual students' experiences and their acquisition and remembering of curriculum content. Procedures, based on the model, for analysing the content, sequence, and timing of content-relevant classroom experiences allowed us to predict, with considerable accuracy, the specific content that students would learn and remember 12 months later (Nuthall & Alton-Lee, 1993).

While the model describes the kinds of classroom experiences that students need in order to learn and remember specific curriculum content, what it does not describe is exactly how knowledge acquisition occurs. We have suggested that a number of information processing activities occur in working memory that lead to the creation of new knowledge constructs that are stored and co-ordinated with other knowledge in long-term memory (Alton-Lee & Nuthall, 1992). It has become very clear from our classroom data that even basic knowledge acquisition in science and social studies curriculum units involves complex and extensive cognitive processes that are strongly shaped by the social processes and cultural structures of the classroom context. What we have yet to identify are exactly what information processing activities are involved in the creation and structuring of new knowledge, and how different classroom experiences develop and shape these information processing activities.

There is increasing empirical and theoretical support for the view that the processes that constitute the mind are socially and culturally constructed (cf. Cobb & Yackel, 1996; Fernyhough, 1996; John-Steiner & Mahn, 1996; Nelson, 1993, 1996). Following the work of Vygotsky on the social origins of the higher mental processes, there are an increasing number of studies of the way social structures and processes are 'internalised' as mental structures and processes (cf. Miller, 1987; Perret-Clermont, Perret, & Bell, 1991; Feigenbaum, 1992). The classroom is

the place where students are required to participate continuously in activities that are structured to organise and facilitate the acquisition of knowledge. It follows that the classroom is likely to be one of the major sites in which students acquire and develop those cognitive processes that are the basis of knowledge acquisition. If this is the case, then it is important to identify and understand how this occurs. Different ways of structuring and managing classroom activities will have different effects on both the type and quality of the cognitive processes that students acquire. To put it more simply, we need to understand how classroom experience shapes those processes that constitute student's minds. Without such understanding attempts to 'reform' teaching and the management of students' classroom experiences may focus on the irrelevant and the trivial and leave untouched those aspects that have the most profound and long-term effects on students' intellectual development.

This article is divided into five sections. The first section contains an account of the methods used to obtain the data in our studies and a brief description of the model of knowledge acquisition that we have developed from these studies. This will serve to introduce the reader both to the model itself and to the kind of detailed classroom data on which this article is based. The second section will focus on what a student's mind must do to acquire curriculum knowledge from classroom experience. How does a student experience typical classroom activities in science and social studies units and what is required in order to extract and make sense of the information available from that experience? In the third section I will examine the process that must occur if the structures and processes of classroom activities are internalised to become the cognitive structures and processes involved in knowledge acquisition. What kind of transactional relationship exists between the external world of the classroom and the internal world of the student's mind when transfer occurs between the two. In the fourth section, which is the major section of the article, I will identify those information processing activities that are used by students to convert classroom experience into knowledge, and the way those activities are shaped by the social processes and cultural structures of the classroom. The final section will summarise the arguments and evidence that support the view that classroom experience shapes those knowledge acquisition processes that constitute the developing minds of the students.

THE DATA, THE METHOD AND THE MODEL

We have now completed a series of five studies of how students learn from their classroom experiences in typical, self-contained, science and social

studies units. Each of the teachers in our studies selected and designed their own unit and carried it out as a standard part of their year's program. Each unit involved a variety of class activities such as class discussions, seatwork exercises, and practical tasks (e.g., keeping a daily record of the weather, researching in the school library, building a model of a medieval village). Each unit was centered around a broad topic (e.g., the weather, the Middle Ages) and related spelling, writing, and reading activities were integrated into the units. The nature of these curriculum units was very similar to the typical American social studies units described in detail by Stodolsky (1994).

It is important to note that these studies were not studies of 'reform' classrooms. The teachers were experienced and competent, but not part of any experimental program. We (the researchers and additional observers) were invited into the classrooms on the understanding that we were there to observe the routine experiences of students during typical science and social studies programs (Nuthall & Alton-Lee 1993, 1995).

Each study consisted of a detailed analysis of the experiences of selected students through the course of the unit. Each study took place in a different classroom and consisted of the following steps:

1. Test development: Interviews were carried out with the teacher about the expected and possible learning outcomes for the unit, and with students in other classes about their understanding of the topic. Written tests (of up to 230 items) were developed on the basis of these interviews to assess intended and possible student learning.

2. Familiarisation and training: Prior to the unit, recording equipment was set up in each classroom, observers trained, and time allowed for the teacher and students to become familiar with the observers and the recording equipment.

3. Student selection: After discussion of student characteristics with the teacher, 3-6 students were identified who represented differences in ability, gender, and ethnic origin. The experiences of these students were continuously observed and recorded throughout the unit. Their identities were not known to the students or the teacher until after the unit.

4. Pre-tests: The outcome tests were administered (read) to the class 2-3 weeks before the unit.

5. Recording student experiences: During the unit, observers, videocameras, and broadcast microphones (worn by each student), made continuous recordings of the behaviours and language of the selected students. Records were made each day of all that students read, wrote, and saw. Students self-recorded relevant out-of-class activities such as homework.

6. Immediate post-tests and interviews: The outcome test was administered again 2-3 weeks after the unit, and the selected students were interviewed about their understanding and beliefs about the test-item content, and their memory for content relevant classroom experiences.

7. Long-term post-tests and interviews: About 12 months after the unit, the tests were re-administered and the interviews repeated. These last two steps were varied in several of the studies by interviewing only in step 6 or step 7.

8. Creation of concept-files: For each concept, proposition, or principle assessed in the outcome test, a 'concept-file' was created for each student that contained the records of all experiences the student had that were related in any way to that concept, proposition, or principle. Each concept-file was then analysed to identify the information-content, sequence, timing, and other significant characteristics of the relevant experiences (Alton-Lee, 1984).

Details of each of the studies referred to in this article, and of the selected students in each study, have been set out in Table 1.

Insert Table 1 about here

After data was obtained in Studies 2, 3 and 4, a model of student learning processes was developed and used to predict, retrospectively, the learning outcome on each of the item files for each student in each study. The results of those predictions have been reported in Nuthall and Alton-Lee (1992, 1993).

According to this model, when students engage with concept-relevant information, their minds construct a representation of that information in a working memory that remains there for about two days. If further representations of information relevant to the same concept are not created in working memory within those two days, the earlier representation disappears. If further concept-relevant representations are created in working memory within the two days, they interact and remain there for a further period. If a student engages with relevant content on three or four distinct occasions (so that at least three or four different representations of content-relevant information come together in the working memory) then a more permanent representation of the concept is constructed in the working memory and transferred to long term memory. The student has, as it were, acquired the concept. This process is represented schematically in Figure 1.

Insert Figure 1 about here

The full account of the model provides details of how different kinds of concept-relevant information are handled, how the process is affected by the context and the involvement of the student and by differences in the kinds of concepts being acquired (see Nuthall & Alton-Lee, 1992, 1993). The following example of how Joy (one of the selected students in Study 6) learned that rain almost never falls in Antarctica will serve to illustrate the kind of information processing and learning that is implied in this model.

Joy first encountered the idea that there was no rain in Antarctica on the second day of the unit when the class watched a video of conditions in Antarctica. During scenes of vast plains of snow-covered ice, the narrator said:

> ... Another surprise is that it doesn't snow as much as you'd expect, except around the coast. Almost no snow falls on the high central plateau. In fact less moisture falls here each year than in the Sahara desert, making Antarctica overall the driest continent. ...

According to the model, a representation of this information is created in Joy's working memory, structured by, and loosely attached to, those concepts that Joy needed to make sense of the statement, e.g., her concepts of the Sahara desert, moisture, the central plateau, etc.

After the video, the teacher invited the class to recall the most interesting things they had learned from watching the video.

> Teacher: OK. Put your hand up if you've learnt one thing from that [video] and you might like to share it with us. OK. Leigh?
>
> Leigh: It's um, it's a dry place.
>
> Teacher: It's one of the driest places in the world. Why would it be a dry place do you think? ... That's something that surprised me, that it's a dry place. Good.

Later in the discussion, Joy's neighbour Jane raised the same point.

> Jane: It's even drier than the Sahara.
>
> Teacher: OK. That the, that Antarctica is drier than the Sahara Desert. That might be a really interesting thing to find out. Why is it drier than the Sahara Desert? OK.

As Joy made sense of the statements made by Leigh, Jane, and the teacher, her mind created further representations in working memory that, because of their similarity, would attach themselves to the earlier representation (from the video) of how dry it is in Antarctica. At this stage, however, these representations would be loosely connected to each other and to those 'parent' concepts that were implicated in creating them. Without further relevant experiences, these representations will disappear or be absorbed back into their 'parent' concepts.

Two of these 'parent' concepts will be the concepts of 'dry' and 'moisture' that, taken together, imply that there would be no rain in Antarctica (as in the Sahara).

The next day Joy was involved in a discussion with other students that focused directly on rainfall. The group was carrying out a task in which they had to study a set of photographs of people working in Antarctica and decide what the people were doing. In one photograph, the people appeared to be using a weather recording instrument.

Maude: Studying weather, yeah.
Paul: But this could be rainfall, rainfall for the week.
Koa: Huh?
Paul: Could be rainfall for the week.
Koa: Could be.
Maude: How do you know rain falls?
Joy: I didn't know rain falls in Antarctica.
Paul: Rain does fall in Antarctica.
Maude: Amazing!
Paul: That's what turns this into ice.
Maude: I thought, I thought, I thought it was dry.
Paul: So it still has a bit of rain.

In this discussion Joy used the information in her working memory to make the claim that it does not rain in Antarctica (I didn't know rain falls). However, Paul claimed that it did rain in Antarctica and Paul was usually credited with knowing a lot about Antarctica. However, within the group, her belief was gently but persistently supported by Maude (How do you know rain falls?, Amazing!, I thought, I thought, I thought it was dry). In the end, Paul conceded his mistake, almost (So it still has a bit of rain). Joy's working memory now had a representation of this discussion attached to the previous representations about it being dry in Antarctica. It included the argument with Paul as well as the information about rain. Because of the number of representations now created in Joy's working memory, they would now form a network of their own that would bind them together as a relatively independent knowledge construct about rainfall in Antarctica.

The next day Joy read an article about a geologist (Kathy Cashman) that referred to the lack of rain.

Kathy found distinct advantages in Antarctic fieldwork ... There are no bugs, no rain, no trees or shrubs to get in the way.

The representation of this information (with its connections to the narrative account of Kathy Cashman's work) would supplement and strengthen the newly forming knowledge construct. There would now be a sufficient number of related representations in Joy's working memory for the new knowledge construct to take on a life of its own as a part of the growing network of knowledge about Antarctica that Joy had stored in her long term memory.

On the last day of the unit, the students were required to write a report of what they had learned about Antarctica. Joy wrote a list of nine facts, including: 'It hardly ever rains in Antarctica. ... Antarctica is the driest country'. It was now clear that Joy believed that it almost never rains in Antarctica. By writing it down, she both expressed her newly acquired knowledge and added a further, elaborating representation.

Our model of learning predicts that, for a student to acquire knowledge of a proposition like 'rain hardly ever falls in Antarctica', the student needs to experience three activities in which the relevant information is fully available to the student. Where the information is partial, indirect, or implicit, further relevant experiences are required (see Nuthall & Alton-Lee, 1993, for details of the prediction procedures).

For Joy, the first two experiences involved indirect information ('one of the driest places in the world'), but these were followed, within a short time (the next day), by a further three experiences involving more direct information (peer discussion, reading, writing a report). Taken together, these experiences should have resulted in Joy understanding and remembering 12 months later, that it almost never rains in Antarctica. In fact, Joy responded correctly to the short-term test question about rain in Antarctica, and in the interview 12 months later, she said:

> It [rain] almost never falls. ... It's um ... it's too cold for it or something I think it is. It freezes up into snow or something.

Not only did Joy recall the proposition that rain 'almost never falls' in Antarctica, she also provided an explanation to go with it, suggesting, as our model predicts, that knowledge continues to evolve in memory through its connections with other related knowledge.

The 'working memory' identified in Figure 1 is not intended to be seen as some kind of compartment or fixed location in the mind. The term is intended to refer to a working area in memory, set up by a specific set of experiences and their relationships to existing knowledge. Such a working area is very similar to Baddeley's description of a 'domain of knowledge' (Baddeley, 1982). It is an area in

memory defined by those locations in memory where relevant prior knowledge has been activated by the new experiences.

We have recently completed an analysis of student learning of the content of all the items in the tests for Study 6 (the Antarctic unit) using this model to predict what the five selected students would learn and remember from their classroom and related (e.g. homework) experiences. The results showed that the learning outcome for each student could be accurately predicted for about 80% of the items. This was the same level of prediction that we had found for Studies 2, 3, and 4 (Nuthall & Alton-Lee, 1993). The details of the predictions for Study 6 are set out in Table 2.

Insert Table 2 about here

In this table, the columns headed 'correct' list the numbers of items for which the outcome was correctly predicted. The columns headed 'wrong' list the numbers of items where the prediction proved incorrect. The percentages refer to the percentage of items for which the outcome was correctly predicted. The items for which predictions were not made were those that the student answered correctly in the pretest ('already known').

What this model implies is that, as a consequence of a sequence of relevant experiences, processes occur in a working memory that result in knowledge being acquired and stored in long term memory. The model defines the sequence and nature of the class experiences that produce knowledge acquisition. What it does not define are the processes that must occur in working memory, or how students might acquire and develop these processes. It is the purpose of this article to try to define the nature of these knowledge acquisition processes and how it is that students acquire and develop their skill in using them.

There are two kinds of evidence available in our data that allow this to be done. First is evidence about how students experience classroom activities and how they talk about those activities. What is it that a student's working memory must do to make sense of the information the student encounters during classroom activities? The second is evidence about the activities students engage in as they encounter the information that they use to construct new knowledge. Our model of learning allows us to identify those activities and those moments when critical aspects of knowledge construction are occurring (see the example of Joy, above).

In the next section, I will examine the first kind of evidence. The second kind of evidence will not be examined until the fourth section, after I have, in

the third section, described the process of internalisation and the conditions necessary for students to acquire cognitive processes from classroom experience.

THE CONDITIONS OF KNOWLEDGE ACQUISITION IN THE CLASSROOM

Our data suggests that there are two important aspects of students' classroom experiences that must determine how they process those experiences during knowledge acquisition. The first has to do with how classroom activities organise or structure student experiences. The second has to do with how students perceive and structure the information they acquire from their experiences.

1. The sorting and collating of dispersed and disorganised information

Our data on student learning shows that, within a programme that involves a variety of activities, students do not learn the same things. Students vary in the way they attend to, and become involved in classroom activities. They vary in what they find interesting and in their understanding of their experiences. As a consequence, each student's learning experience is largely unique. One important consequence of this is that the stream of information a student experiences that is relevant to a specific concept is likely to be, from that student's point of view, dispersed and disorganised. Even in tightly structured activities, information is not encountered in neatly packaged, sequentially organised units. Even if it were, each student would interpret it, and see its implications and connections, in different ways. The following is an example of how this occurs. It is an excerpt, taken more or less at random from a talk given by a visiting speaker (MC) on Day 6 of the unit on Antarctica (Study 6). The speaker was a geologist who had been invited to talk to the class about her work as a scientist in Antarctica. The excerpt (of about 6 minutes) was from near the beginning of her 40 minute talk. At the beginning of this excerpt, she showed a photographic slide, taken out of a plane window, of icebergs, and floating ice in the sea off the coast of Antarctica. The numbers in the excerpt represent quarter-minute intervals, numbered sequentially from the beginning of the day's work on the unit. The dots (...) represent places where text has been omitted for brevity.

MC: ... icebergs like this, floating ice, pack ice and that's a time I really felt, I actually am going to get there ... there's always a chance the plane will get turned back. (71) ... when there's a blizzard on the ground ... (72) ... So, you really believe you're there (73) when you see the ice floes. Right? Then, then you turn and look the other way out the plane window and there's miles and miles and miles and miles of mountains. Antarctica is not flat. It's a mountainous country. (74) ...

MC went on to show more slides of a husky dog team, of the buildings at Scott Base, and of her expedition members' tents on snow. As she showed the slides she continued to talk about her work. Analysis of this 6 minute extract from her talk (and the slides that accompanied it) showed that she included content relevant in some way to 10 items in the post-test. The information required to answer these 10 items is listed below (with the item numbers).

1002. Antarctica is made up of land and ice and snow.

1009. Antarctica has many mountain ranges.

1016. A glacier is a river of ice.

1021. Pack ice is broken ice floating in the sea.

1024. An iceberg is a large piece of ice floating in the sea.

1028. Husky is the name given to a kind of dog that is suited to cold snowy conditions.

2012. The snow that piles up high around the huts in Antarctica is there because it is blown there by high winds.

2018. Scott Base is the name of the New Zealand base in Antarctica.

2025. The big transport planes that fly in to Antarctica have to land on areas of flat ice.

3017. When they go to Scott Base, many people miss the smells they are used to at home.

Figure 2 shows the way the content of these items was dispersed through these 6 minutes of her talk. In this figure, the time is calibrated across the bottom of the figure using the numbered quarter minute intervals. Each numbered box represents the time spent on the content of that numbered item. For example, during her talk, there was some reference to the content of item 1002 during the quarter-minute intervals 72 through 75, and then a further reference to this content during intervals 88 through 89, and intervals 92 through 93.

Insert Figure 2 about here

It is important to note that reference to an item does not mean that the full answer to the item is contained in the reference. For example, item 1002 is about the fact that Antarctica, unlike the Arctic, has land beneath layers of ice and snow. During the relevant time intervals, MC referred to 'ice floes', 'miles and miles of mountains', 'Scott Base is, it's right on the edge of the land' and showed a slide of icebergs, snow, and pack ice. The implication of this information, taken together, is that Antarctica has underlying land as well as ice and snow. Similarly, the reference to icebergs is not a definition of the kind required to answer item 1024. Instead, there is a picture of icebergs, and the speaker refers to them as 'icebergs'.

Taken together with other information, this brief experience builds into the students' accumulating knowledge about icebergs, but is not, in itself, a complete definition.

What is evident from Figure 2 is that, at any one time, a student is likely to be exposed to information that is relevant, or partially relevant, in different ways, to several different curriculum concepts or propositions. While the content of the talk is itself an orderly narrative, its relationship to the content of the unit, as a whole, is complex and constantly changing. A similar analysis of teacher-led class discussions, or of groups of students working together in a structured activity, shows even more complex patterning of curriculum relevant information. The implication of this dispersed and entangled patterning of information is that a student's mind must be constantly engaged in extracting information from experience, and sorting and organising that information. This suggests that students must have some kind of working memory that holds experiences in temporary storage while connections with existing knowledge are identified and used to sort and co-ordinate related experiences. It also implies organising principles or structures that determine how dispersed experiences get connected to each other.

The existence of such a working memory is also confirmed by our finding that isolated experiences, or experiences that do not get connected to other incoming experiences, are rapidly forgotten. Working memory acts as a kind of 'time window' (Fivush & Hammond, 1989; Rovee-Collier, 1995) that remains open for about two days. Experiences occurring outside the 'time window' have no effect on learning.

2. The creation of implications and connections.

An analysis of the ways in which students recollect their classroom experiences also supports the view that their minds are constantly engaged in organising and creating coherent relationships between incoming information. The following example illustrates this kind of evidence. The example will be described in some detail because it also shows the way in which new knowledge is organised as a coherent, logically consistent structure, made up of those elements of experience that are available in memory.

Kim was a 10 year old student in the class that was studying life in Medieval England (Study 2). The teacher designed the unit to include a variety of activities (e.g., building a model of a Medieval village, listening to the story of a page boy's life, completing worksheets on significant events in the Middle Ages, spelling activities with key words).

One of the many pieces of information that the teacher expected her students to learn was that, in medieval England, a public 'charter' was a document that set out 'the rights of free men'. The most famous example was the Magna Carta. The pretest showed that before the unit Kim did not know what a charter was.

Information about charters came up towards the end of the unit when the class were studying medieval towns. On Day 16 of the unit, Kim completed a worksheet on the Magna Carta. This included a picture of King John signing the Magna Carta surrounded by bishops and knights. The text under the picture read:

> ... The barons and bishops have gathered at Runnymede and made him listen. They have written a GREAT CHARTER (Magna Carta). It sets out all the rights of free men. It means justice and fair taxes ...

Kim wrote answers to the worksheet questions about the Magna Carta (e.g., True or False: Magna Carta set out all the rights of free men. Magna Carta means 'Great Charter'). Later that day the teacher discussed the worksheet with the class.

> Teacher: ... Right, that picture. ... So a group of rich barons got together and they worked out some ... regulations, rules, um, to say they could do this, they could do that. ... They wrote all these down and they went to see King John and they demanded that he sign this agreement. ... This agreement that King John signed has got a special name. It's called the Magna? Anybody want to tell me the other half? Bianca?
>
> Bianca: Carta
>
> Teacher: ... Called the Magna Carta. And it means a great charter. An important document, an important agreement. Thanks. Um, right ... The great charter, the Magna Carta, and the next sentence tells you what it does. It sets out all the rights for the free people.

The teacher then went on to check the students' answers to the questions on the worksheet. Two days later (Day 18), the class discussed living in medieval towns. The discussion touched briefly on the concept of a charter.

> Teacher: ... If a town was given its freedom, it was made in a written promise, and that promise was called the – ? Let's see how good your memories are? Last week we talked about a very important promise that had been made. What do you think this promise was called?
>
> Student: Magna Carta.
>
> Teacher: Now that was a very important one that King John made. You're quite right about that. This, this is just an ordinary town, um, agreement.
>
> Student: A charter?
>
> Teacher: Right. It was called a charter. Now I wanted to say something else ...

Following this discussion, the teacher wrote a set of sentences on the blackboard about living in a medieval town ('The market place was the centre of town. People bought and sold goods there, the town crier made announcements, and it was a place where criminals were punished. A charter was a written promise giving the town its freedom ...'). The students were asked to copy this set of sentences into their project books. Each of the students was also given an outline picture of a town market place and asked to paste it in their project book alongside the sentences. The picture (Figure 3) was a busy scene with people, stalls, animals, and a man in the stocks being pelted with eggs.

Insert Figure 3 about here

During the interview soon after the unit, Kim recalled that picture, and coloring it at home.

Interviewer: And you remember a picture in your book. What was in the picture?

Kim: Oh. There was, ah ... it was in the middle. It was, um, this corner. Say that was where this man was in the streets, this was a corner with a whole lot of vegetables there, and a man was selling them, and the guy bought it and was throwing. This man bought it, some, was throwing eggs at the um, person in the stocks. ...

Interviewer: Did you remember coloring it in at home or at school?

Kim: Oh, um, at home.

Interviewer: Did you show it to anybody at home?

Kim (Laughing): Oh Mum.

Interviewer: What did she say about it, did she talk about the picture?

Kim: Oh, she said it was good coloring in.

The next day (Day 19), the word 'charter' came up during the morning spelling activity. The teacher had written a set of sentences on the blackboard, with a word missing from each sentence. The teacher discussed each sentence with the class and the students had to learn the missing word for the weekly spelling test. One of the sentences for this day was 'A written promise called a _____ showed how a town had been given its freedom.' The class discussed each sentence.

Student: [reading sentence from blackboard]: A written promise called a 'something' showed that the town had been given its freedom.

[Student knocks on door of classroom, enters to get lunch orders].

Teacher: What was it called? Celia?

Celia: Charter?

Teacher: Right. [To lunch-order student] Are you coming with the charter?

Lunch-order student: Any lunch orders? ... [gets lunch orders from students]

Teacher: Right. Good girl. I wonder if anyone can tell me what the root word is for charter? Bev?

Bev: Chart.

Teacher: Right. –Er. Chart – er.

It was part of the teacher's practice to help students to find 'root' words within words to help them with their spelling. This discussion continued for the other sentences on the blackboard about medieval towns, mayors and market places. Later Kim copied these spelling sentences into his project book.

This was the last occasion on which Kim experienced any direct reference to a 'charter'. There were, however, other discussions of life in medieval towns. On one occasion, during the showing of a filmstrip on life in the middle ages, the teacher drew attention to the town-crier, and to the stocks.

Teacher: ... Now there's the town market place, everybody buying and selling their goods ... This is the one I wanted to talk about. There's a man there standing on the steps. He's dressed in red and he's got a parchment in his hand. Who's he? Susan?

Susan: Town crier.

Teacher: What's the town crier's job? Bianca?

Bianca: He tells them messages from the townspeople.

Teacher: Why are messages told? We don't tell messages, if we want to tell things. We usually write them down. Why are they told? Belinda?

Belinda: People can't read.

Teacher: Okay. That's about the only way they can get to know. ... Um, we mentioned about punishments. You can see a gentlemen there, he's got his feet in something. What do we call the something? ... Kristie?

Kristie: The stocks.

Teacher: Right. The stocks. I guess it'd be pretty uncomfortable sitting there all day long. And the people who pass by are certainly not going to pass by and say nothing.

Student: They're going to throw things. ...

By the end of the unit, Kim had been confronted with a range of different information about a 'charter'. Initially it was about the Magna Carta and the 'rights of free men'. Later it was about life in medieval towns and the charters that established their freedom. When we interviewed Kim after the short-term outcome test, he described a 'charter' in the following way:

Kim: Charters - I think it was showed people directions for moving about the towns. Cause there was charters in the middle where the market was. I think, I think that. Um.

Interviewer: Describe one to me.

Kim: Um. Oh, I don't know.

Interviewer: Anything you can tell me will help.

Kim: Um, I can remember a person in the middle of the road with a scroll. Um. And reading out things. Yeah, Ms B was telling us about it, um. I hope I haven't muddled.

A year later when we interviewed Kim again to find out how much he still remembered, he described a charter in the following way.

Interviewer: Okay, have you ever heard the word charter?

Kim: No, but I can, I think ah, no um there's this thing I can remember, well there, something, in the picture there was a crossroad, well with lots of roads joining into it and there was the stocks and people were throwing eggs at this person in the stocks, and then I think I heard something about a man stands in the middle there and if someone wants to go somewhere they go and ask him where to go. I think.

What Kim 'learned' about the Medieval charter from the content of his classroom experience was not what the teacher intended, but it was a coherent and logical interpretation of those elements of his experience that he recalled. The conflict between the charter as a statement of the rights of free men and the charter as a statement guaranteeing the freedom of a medieval town, had been resolved in favor of the medieval town version. Kim had forgotten the connections between the Magna Carta and the 'rights of free men'. According to Piaget (1978) such forgetting occurs when the new material is not understood adequately, i.e., when no appropriate connections are made with related knowledge. Instead, Kim recalled that charters were connected with towns, market places, town criers and charts. Market places were associated with cross roads and people in stocks; town criers were connected (in the same class discussion) with the stocks; town criers were also associated with reading scrolls and making announcements. Kim associated the root-word of charter (chart) with maps and directions, presumably from his own prior knowledge of the meaning of the word 'chart'. Kim created from this set of associated pieces of information a new knowledge construct that integrated them into a coherent story. With the passage of time this story drifted further from the original information, but still retained its underlying coherence.

A new knowledge construct of this kind is not just an internally coherent structure. It is bound up within a network of other related knowledge structures that also determine both its content and how it is used. For example, the picture of the medieval town (Figure 3) that Kim colored at home (and his mother praised) provided a link to several other new knowledge structures that Kim constructed. He used the picture as the basis for answering a question about fire in medieval towns. When he was asked what was the greatest fear of people living in medieval towns, he identified 'fire' and explained his answer by referring to the picture.

Kim: I can remember, um, in the picture, ah, I could imagine how fire spreading through there, spreading through it. 'Cause the houses was very, very close together. Like it's one big motel about as, um, big as a street. Yeah, not a fence or a garden, just the one big block of houses joined to the next one. No alleyways through.

Interviewer: Right, and you can remember Ms B saying that.

Kim: No.

Interviewer: Well how else might you have worked that out?

Kim: Ah, by that picture. (Laughs).

In fact, the connection that Kim made between the picture and fire was not entirely his own. The teacher did talk about fire, but in a class discussion of the 'black death' and the great fire of London that followed it. As Kim recalled that discussion, he made the connection between the black death, the fire, and the way the black death spread through inadequate sewage disposal.

Kim: Well, all is I can remember is, ah, yeah, I can remember ... she, Ms B telling us, something about the black death and that was a disaster and so was fires cause of the, the houses were joined together. ... And um, I can remember I drew a picture, I mean I colored in a picture, where it was um, none of them had, there was no such thing as rubbish bins, I think, they just threw all their rubbish out in the streets and there was kind of a wee ditch in the middle of the road. And it was in there.

What emerges from this analysis of Kim's recall of information about charters, medieval towns, stocks, cross roads, town criers, rubbish in the streets, fires, the black death, and so on, is that Kim organised the information he extracted from his experiences into a set of inter-related coherent stories or knowledge structures. Some of the connections were missing (e.g. between the Magna Carta and a charter), but taken together these inter-related stories formed an extensive network of related ideas and information. The components of this extensive network reflect what it was that Kim 'understood' by each of the component pieces of information. It is in this sense that 'understanding' involves making connections between related experiences.

In our analysis of the ways in which students answer achievement test items (described in Nuthall & Alton-Lee, 1995), we found extensive evidence of these individually constructed networks of information and related inferences. We found that students used these networks as the basis for interpreting and validating not only new information, but also their recollections of past experience. They used them to reconstruct and to supplement, correct, and validate what they recalled.

To summarise this section, the evidence from our observations, recordings and interviews suggests that, in order to understand and remember the

information they encounter during classroom activities, students must possess some kind of working memory or set of working spaces in memory that sort and organise incoming experience on the basis of the connections that are identified between incoming experiences and prior knowledge structures. Furthermore, once new knowledge structures have been created, they do not remain in long-term memory in an inert state. Each of the components from which they were constructed, and each of the related knowledge structures to which they are connected, are constantly in use in the interpretation of new experiences and the construction of new knowledge constructs. What is implied by the existence of such set of working spaces in memory, and of a dynamic knowledge construction process, is the existence of organising processes or structures. These are the cognitive processes and structures that underlie the acquisition of knowledge. In the next section, I will examine the way such underlying cognitive processes and structures are themselves acquired.

INTERNALISING COGNITIVE PROCESSES AND STRUCTURES

The view taken in this article is that the processes and structure that underlie knowledge acquisition are themselves acquired by students. If working memory is seen not as some kind of biological or genetically acquired compartment in the brain, but as an organisational aspect of the way the mind processes experience, then understanding how working memory operates is closely related to understanding how working memory is acquired or develops out of experience. If working memory has a biological location, then it is that area of the brain where current experiences are being processed. The location of this area will be constantly changing as experiences change. Since, as I indicated in the previous section, there is a constantly shifting dispersion and overlap of incoming experiences, there are going to be multiple working memories (or working spaces in memory) in operation at any one time.

While the biological basis of working memory can only be a matter of speculation, what is clear from the evidence in our data is that a large amount of a student's prior knowledge is involved in the interpretation of experience at any one time. Working memory is defined as the area enclosed by that prior knowledge. As experiences change, so does the area that is defined as working memory.

It follows from this definition of working memory that the processes by which it works are determined by the knowledge structures embedded within the knowledge area in which it is working. In other words, the cognitive processes by

which knowledge is acquired are intimately connected with the nature of the experiences and knowledge which are being processed (Baddeley, 1982).

Although not fully argued here, this position is consistent with the view that the basic cognitive processes that constitute the mind are themselves acquired from experience. They develop in the infant mind through their use in interpreting and organising experience. As many theorists, including those working in the traditions of Piaget (1962, 1978) and Vygotsky (1978, 1981), have argued in recent years, how we perceive, represent, and think about the world is a product our interactions with our physical and cultural environment (Cole, 1996).

> '... the nature of the individual's mental functioning can be understood only by beginning with consideration of the social system in which it exists' (Wertsch, Tulviste & Hagstrom, 1993, p.338)

The process by which we acquire the basic cognitive functions of the mind has been described as 'internalisation'. The structures inherent in the physical, social and cultural worlds are transformed in some way and become the operating structures of the mind. It is this transfer or transformation that is referred to as internalisation. In this section, I want to examine the process of internalisation to see how it might work in the classroom. Most of the accounts of internalisation have focused on it as a developmental process (Lawrence & Valsiner, 1993). In the work of both Piaget and Vygotsky internalisation occurs as the mind (or higher mental processes) develops in the young child. Consequently, most of the relevant research relates to infants and younger children. To make it relevant to the classroom, it will be necessary to extract what appear to be the essential elements of the process and translate them into the context of classroom activities.

The first point to note when trying to understand internalisation is that it is a process. It does not occur instantly or without involving a variety of related processes. As both Piaget (1978) and Gal'perin (quoted in Arievitch & van der Veer, 1995) see it, it consists of a series of inter-related steps. The process begins with an external activity or set of behaviours that a child learns to perform within a social and physical context by trial and error, by imitation, or through guided participation. As the child becomes progressively more competent at the activity, the child becomes aware of the activity and its components as something separately identifiable from the context, or larger activity sequence, in which it is carried out.

The process of becoming aware of the activity as a distinct, separable entity, takes place through continued practice, especially through the kinds of practice that we call imitation and play (especially pretend play). It is also aided by the use

of language to name and describe the activity. Imitation, pretend play, and naming, each require the isolation of the activity from its original contexts and the identification of its essential or defining components. Even a young child cannot imitate the action of talking on a telephone with curved stick or banana unless the child is aware of the essential elements of telephone-talking without the presence of a telephone.

This progressive identification of the essential elements of an activity has been described as the identification of the structure or rules of the behaviour. Structure implies identification of the sequential relationships between elements of the behaviour. Rules imply the ability to control and guide the behaviour. Rules also imply the possibility of replacing one behaviour with another, of knowing which behaviours are the equivalent of others for certain purposes.

Piaget (1978) argued that what is internalised is not the behavior but the system that organises the specific acts involved. A system consists of an action or set of actions with their antecedents and consequences, the contexts in which they are found, and their relationships to other actions, especially those actions that have opposite or contradictory effects. To say that a system gets internalised does not imply that specific activities or processes get carried out in the head. It implies that whatever goes on in the head is organised in a way that parallels the organisation of external behaviour. It is the set of relationships, or the logic of the system, that gets internalised, not just the behaviors.

> ... an [mental] operation is not a representation of an act ... it is a 'signifying' not a practical action in that the connections it uses are implicative, not causal. (Piaget, 1978, p.222)

While Piaget was primarily concerned with internalisation of the structures of activity systems relating to the physical world, Vygotsky was more concerned with internalisation of the structures of communication and language. Vygotsky talks of the internalisation of social language as the basis for higher mental processes. However, like Piaget, he claims that it is the essential underlying structures that are internalised, not the surface features (Feigenbaum, 1992). Mental actions are 'transformed and abbreviated material actions' (Arievitch & van der Veer, 1995, p. 118). For example, the specific words and grammatical structures needed for effective social communication with another person, disappear. What gets internalised are those underlying knowledge structures and concepts that are embedded in language as a cultural tool. Thinking as talking to oneself retains the embedded cultural structures of language, not the conventions that are specifically designed to make social communication effective (Vygotsky, 1979, 1981).

On the other hand, in Bakhtin's analysis of the relationship between external activities and internal mental processes (Wertsch, 1991; Ramirez, 1992) it is precisely the dialogic and communicative features of language that are internalised. Because language is the medium of communication, internalisation involves coming to reproduce, in the mind, the communication process. Internalising the structures of language means internalising the roles of both the speaker and listener and the interaction between the two.

Both Piaget and Vygotsky see internalisation as progressive. External behaviour systems, whether these are primarily in the sociocultural or the physical world, are internalised as they are mastered by the child. Two types of development go on simultaneously. There is the practical development that occurs as the child learns to control and co-ordinate actions and solve problems, at the practical and/or social level, and there is the mental development that occurs as the structures or rules of the evolving practical systems are progressively internalised.

Piaget identifies a close relationship between understanding and internalisation. A child's understanding of what she/he is doing is a function of the extent to which the system has been internalised. So for example, if a child is asked to recall or draw a picture of a solution to a problem, the child will give an account or draw a picture that reflects those parts of the solution that have been internalised. This is why children's drawings have distinctive forms of their own. The drawing (or recall) is the product of the system of relations or structures that the child has internalised. So, for example, a child's drawing of a person does not represent what the child sees, but represents those proportions and relationships between parts of the body that the child has internalised.

If internalisation occurs in much the same way in the classroom as it does in early development, then it should have three important characteristics. First, internalisation should occur as students acquire expertise in the activities of the classroom. Internalisation is the process of acquiring expertise. From a Piagetian perspective this involves becoming aware of an activity as a distinct entity with its own patterns of causes and effects and of relationships to other activities. The student comes to identify the essential components of the activity as a system, and to know how to control and use the activity. This involves the capacity to 'run' the activity in the mind, varying its components predicting the consequences of these 'mental' variations.

From a Vygotskian perspective (e.g., Rogoff, 1995) the process is one of apprenticeship in which the student acquires the rules of participation as an expert in the social activities and cultural rituals of the classroom. The student comes to acquire this expertise through guided participation in these social

activities and cultural rituals. To the extent that classroom activities are always socially and culturally structured, what will be internalised will be both social and cognitive.

> '... thinking and cognitive development involve participating in forms of social activity constituted by systems of shared rules that have to be grasped and voluntarily accepted.' (Nicolopoulou, 1993, p.14)

The second important characteristic of internalisation is the transactional or interdependent nature of the relationship between the external and internal development that is taking place. The development of expertise is dependent on internalisation, as internalisation is a consequence of increasing expertise. There is, at it were, an inter-weaving of the external and the internal aspects of development (Cole, 1996, p.135). Salomon (1993) has described this as a transactional relationship in which the internal and the external develop interactively and stimulate each other's development. Control of the activity progressively transfers, however, from external conditions to internal processes.

Third, internalisation is not a developmental process in the sense that it occurs at a specific age or stage in a student's life-span. Classroom activities are themselves the product of the evolving relationships between teacher and students, and of the evolving culture of the classroom. Becoming an expert must be a continuous and always incomplete process as the activities designed by the teacher are translated into practice within the cultural and social dynamics of a specific classroom.

From this perspective, internalisation in the classroom can be identified in the ways in which students negotiate their involvement in classroom activities and come to manage and develop expertise in those activities. The answer to what is being internalised in the classroom lies in what students need to do to keep on becoming expert in classroom activities. From the perspective of knowledge acquisition, it consists of what students need to do to become expert at acquiring knowledge through constantly evolving classroom activities. One way of summarising this position is to redesign the diagram contained in Figure 2 so that it incorporates the students' involvement in information processing activities in the classroom. If the concept of a working memory, as the location where incoming experience is organised and integrated with prior knowledge, is retained, then working memory needs to be expanded to incorporate the external world of classroom activities. This has been done in Figure 4.

Insert Figure 4 about here

The difference between Figure 2 and Figure 4 is that the classroom context has been specifically identified as part of working memory. The lines that identify the working memory have been made to appear permeable, so that the distinctions between working memory and its social context are blurred. Working memory has become, as it were, 'distributed' across the boundary between the private and the social worlds of the classroom (Lave 1991).

If this is translated into actual classroom activities, then we need to look for evidence of the transactional relationship between the external and the internal processes of knowledge acquisition. Our data suggest that such a transactional relationship does exist, but in order to understand how it works, the sociocultural world of the classroom needs to be differentiated into at least three distinct dimensions. Students interact with curriculum content in the public world of classroom activities in which the teacher has direct control, the semi-private world of small group interactions, and the private 'in-the-head' world of mental operations. Green, Weade, & Graham (1988) have described these worlds as 'frames'. How these three worlds or frames interact with each other is a function of the way tasks and activities are structured. For example, during a teacher-led discussion, the possibilities of peer interactions are restricted and their influence largely shaped by the way the teacher controls the discussion. On the other hand, during small group activities, the agenda of the semi-private world of peer relationships may dominate the way students interact with the curriculum.

1. Participation in teacher-led class discussions

How students participate simultaneously in the three worlds of the classroom during teacher-led whole-class discussions is illustrated in the following example from Day 4 of Study 6. In this example, the private internal world is represented by the self-talk that was recorded on the students' individual broadcast microphones. Using self-talk in this way is based on the assumption that it represents a fragmentary sampling of the private internal world. Extensive research on self-talk (cf. Diaz, & Berk, 1992: Manning, White, & Dougherty, 1994) suggests that it represents a transitional behavior between internal cognitive processing and external social talk that emerges in contexts where the individual is attempting to control or organise internal cognitive processing. Our recordings from individual broadcast microphones have produced a much higher frequency and a much wider range of different forms of self-talk than previous studies that have relied on observers or more distant recording devices (Alton-Lee, Nuthall & Patrick, 1993). The self-talk reported in this, and the following sections of this

article, is not intended to be a direct reflection of the internal mental processes of students. It is intended, however, to provide the best, albeit fragmentary, evidence of how the internal mental processes of the students are engaged at the time the self-talk was recorded. As the discussion at the end of this article will indicate, it is my view that internal cognitive processing is not a unitary process, but like the world of the classroom from which it develops, it is a complex multiple set of parallel processes, only the surface of which is ever conscious, and only a fragment of that ever emerges in self-talk.

In the example below, the teacher was attempting to illustrate the nature of a biological food chain by talking about where humans would fit in such a chain. In this, as in many of the following excerpts from the audiorecordings in Study 4 and Study 6, the left hand column reports the public, teacher-led discussion, and the left hand column records the simultaneous semi-private talk between students and the self-talk recorded on the individual broadcast microphones.

Public discussion	Semi-private and private talk
Teacher: What eats us?	
Paul: Sharks.	Joy (to Jane): I know, what we eat.
Jim: Lions, tigers and bears.	
Teacher: OK. Carl, perhaps we should go backwards then and say what we eat then.	Jim (to self, laughing): Oh my. Lions and tigers and bears. Oh my!
	Jim (to Ben, mimes eating): Lions and tigers and bears. Oh my!
Masako: We eat too much things.	Paul (to anyone): Correct Masako. Correct!
Teacher: Some of us might.	Joy (to self): What we eat.
Teacher: Right. OK. Jill?	
Jill: Fruit?	Paul (to self): Meat. We eat apples, bananas,
Teacher: Fruit. (writes fruit on chart)	oranges, meat, mmm, fish.
Student: (inaudible)	
Teacher: Was that fruit or food?	
Student: Fruit.	
Teacher: Frrruit. Joy?	Jim (to self): Frrruit. Ice cream.
Joy: Fish.	
Teacher: Fish. (writes fish on chart) Yes?	
Sally: Vegetables.	Jim (to Ben): Vegebulls.
Teacher: Vegetables. (writes vegetables on chart)	Ben: Veggies
	Jim (to self): Animanimals.
Jim: Animanimals.	
Teacher: Yes Robin?	Joy (to self): Animals. Meat.
Robin: Pigs. Etc.	Paul (to Robin): Vegetables, yellow vegetables. We eat beef, yeah. (to self) Meat.

The three interacting layers are evident in this excerpt. Paul, Jim, Masako, Jill, Joy, Sally, Robin, and an unidentified student, participated in the public teacher-led discussion. The teacher wrote their contributions on a chart of the food chain. Within the private and semi-private worlds of the students, Joy repeated part of the original teacher instruction to her neighbour, Jane, and then to herself. Jim repeated what he said in the public discussion, first to himself and then to his neighbour, Ben. Later he imitated the teacher's pronunciation of 'fruit' exaggerating the initial syllable of the word. Jim continued this play on words, involving Ben in elaborating versions of 'vegetables'. He then carried the word-play into the public arena by contributing 'animanimals'. Paul picked up

the discussion privately with Robin, giving his own semi-private list of foods, which he finished to himself.

What this example demonstrates is that, while the form of the interaction with the curriculum content is largely set by the discourse structures of teacher-led discussion, students also carry on parallel semi-private discussions that are intertwined with the public discussion. In addition, their self-talk suggests that they carry on internal discussions that parallel, in a similar way, both the semi-private and the public discussions. As these three worlds interact, and students acquire expertise in the tasks that structure these three worlds, they internalise the activities and processes that make up these tasks. Participation is as much personal as public. Not only do students respond to the teacher's questions privately, they also share with each other, their private responses. In the following example, Joy lets Jane know what she was thinking of saying.

Teacher: Jane?

Jane: Crevasse.

Teacher: Crevasse ...

Joy (taps Jane on arm, whispers): I was going to say that.

Jane: Ohh.

Some students privately share responsibility for participation in the public discussion, helping each other to contribute. In the following example, from Study 6, the teacher was listing (on the blackboard) the students' ideas about the jobs that people do in Antarctica.

Teacher: Colin, have you got one?

Colin: Climbers.

Teacher: Good. Do you know any climbers?

Jane (to Joy, whisper): Pilot.

Joy: Yeah, it's up there (on the blackboard).

The students do not just internalise their own role in the teacher-led discussion. They also mimic and internalise the role of the teacher. For example, students evaluate other students' responses. In the following excerpt, the class was discussing the map of Antarctica.

Maude: It's [map of Antarctica] shaped like an elephant's head

Teacher: Pardon?

Maude (laughs): It's shaped like an elephant's head.

Paul (whispered to Ben): It is actually.

In the next excerpt, Paul imitated another aspect of the teacher's role and provided an explanation for the instruction the teacher has just given.

Teacher: ... your interview questions are meant to be included in your booklet.

Student: Do you write your answer (inaudible).

Teacher: When you get the answers, yeah sure. But don't put the answers beside them now!

Paul (whispered to Ben): Well, it would be stupid asking the question wouldn't it?

It is important to note that the semi-private and private discussions are not continuously dependent on the public discussion. From time to time they pursue an independent course of their own. In the following example, a semi-private discussion continued as an alternative to the public discussion. The class was discussing what animals need for food.

Kurt: Could they, could animals just live on water do you think?

Teacher: OK. Well could you, could you just live on water?

Student: No. You need vitamins and stuff like that.

Paul (to self): You can't.

Student: You can but not for long.

Koa: You can but you need solids and vitamins.

Teacher: Right. So you'd have a shorter life span if you just lived on water then would you?

Nell (to Paul & Ben, privately): It's five days.

Paul: No, it works in half days. Three minutes, three days, three weeks.

Ben: (inaudible) live for three weeks without water. Three days without food and things. No, no, no. Three days without food, three weeks without food, three days without water, three days without anything?

Evidence of this kind suggests that, within the context of teacher-led discussions, the three worlds or 'frames' are partly dependent and partly independent of each other. The semi-private and private worlds mirror the structures of the teacher-led discussion. Within the semi-private and private worlds the students enact

both their own and the teacher's roles. The students' involvement in the public discussion reflects the content of their private internal discussion which in turn reflects their prior knowledge and understandings of the content of the public discussion. Similarly, their involvement in the public discussion reflects their involvement with their immediate neighbours. The occasional semi-private discussions that emerge in parallel to the public discussion suggest that students are constantly aware that whatever they say in the public discussion also contributes to the on-going dynamics of their relationships with each other.

2. Participation in small-group activities.

The patterns of participation in small group activities are different from the patterns of participation in teacher-led class discussions. The requirements of the task rather than the patterns of teacher-student interaction provide the underlying structures. For this reason the public and semi-private layers of participation collapse into each other. The students must interpret the task instructions for themselves and for each other, and while they may take on, from time to time, the role of the teacher, it is always within the context of peer relationships. However, the private world continues to operate alongside, and in interaction with, the social world of the group. It is often difficult to decide, even from the evidence available from simultaneous video and audio recordings and direct observation, whether a student utterance was intended for an audience or not. It is probably more accurate to think of student utterances as forming a continuum from utterances clearly directed to a specific other student, through utterances directed to the group as a whole, and utterances directed to no one in particular, to utterances that seem to be 'thinking aloud'. In the examples used in this article, the distinctions between self-talk and social talk should be seen as probable rather than definite.

The following examples illustrate the way students' participation in small-group activities shifts between the private and semi-private social worlds. The first example is from Study 6. During the unit on Antarctica, the students struggled with the idea that there is no usual day and night in Antarctica. Some students understood why this is so, some students thought they understood, and some students wanted to know why. In the following excerpt, Koa asked the others in her group why it is so cold in Antarctica. Ben explained about the angle of the sun and the long, continuously dark winter. Jim tried to help with the explanation.

Jim: It has very, very short days during um, spr...

Ben: It doesn't have any days during winter.

Jim: No, um, no.

Koa: It doesn't have any nights during the winter?

Ben: It's light for six months and dark for six months.

Jim (to self): Yeah, but um oh ... They have ...

Koa: They have spring and autumn?

Jim (to self): Let's see, ah, oh. ... (teacher arrives to talk to group)

Jim's attempt to participate in the explanation slipped back into self-talk as he found he did not know how to answer Koa's question in the face of Ben's confident explanations. In the next example, the students were engaged in the individual task of preparing questions to ask a visiting speaker. The teacher had already talked about how to prepare good questions that related to the topic of the talk and what the speaker was likely to know. Jim was sharing his questions with his neighbours Paul and Ben.

Jim (talking directly to Paul): Oh Paul. I'm going to ask her what was the living conditions like. (to self, looking at own list) I bet she'll, I bet she ... I know what she'll answer. Absolutely excellent. (turning and talking directly to Ben) Nice and cosy and warm.

Jim's self talk reflected his concern about the quality of his question. He tried to predict how she would answer it. His talk shifted from social to private to social, with little change in content. In the next example, the self-talk was a playful extension or imitative echo of the social talk, similar to the imitative echoes that characterise the pretend play of small children. Paul was talking about the pen he was using that contained several different colors.

Paul (to Ben): I thought it [pen] was blue. Ben, I thought it was blue. I pulled the black out and I stuck it into the blue. (continues to self) And I pulled the boo out and stuck it into the boo. (continues writing).

By contrast, Joy's self-talk in the next example anticipated her contribution to the group discussion. She appeared to be rehearsing what she was going, or trying, to say. The group were looking at two photographs of people working in Antarctica. Their task was to identify what the people were doing, and to contrast the two pictures.

Paul: They're studying something. Oh, a little penguin.

Maude: Oh cool!

Paul: In one of them there's a penguin and in the other there isn't.

Joy (to self): The weather.

Maude: I think they're two contemporary [photos].

Paul: Yeah, cause that does look like it's a colour photo.

Maude: Mmm.

Joy: They're just telling the weather or something aren't they?

Paul: Definitely meteorology. I'm not sure about that.

Joy: Yeah. What's that? ... etc.

Joy's interpretation of what the people in the picture were doing was initially an independent private response, reflected in her self talk ('weather'). Later it became a contribution to the group discussion ('they're just telling the weather or something') that Paul translated into a more formal description ('definitely meteorology'). As the examples in the next section will show, the interaction between the semi-private and private worlds of the students during small-group activities is interwoven with, and constantly shaped by, the dynamics of the social processes of the group.

In this section, I have argued that the process of internalisation involves the progressive development of expertise through an increasing awareness of the structures and rules that characterise an activity. Internalising the activities of the classroom means that the student acquires the rules of the activities in the same sense that a child acquires the grammatical rules of a language during the process of becoming a competent speaker of the language. Acquiring expertise and internalising the structures and processes of an activity are two sides of the same process.

During internalisation there is a transactional relationship between the external practice of the activity and the internal use of the rules and structures of the activity. Although the term 'internalisation' implies a process of transferring the external behaviors into the mind, this is not what is intended. The process is two-way. Both the external behavior and the internal structures develop simultaneously.

I have then presented evidence to suggest that the conditions for internalisation occur in the classroom. Evidence from recordings and observations suggests a transactional relationship among the three layers of student participation, the public teacher-controlled layer, the semi-private peer relationship layer, and the private, primarily internal layer. Each of these reflects and interacts with the other, setting up the conditions for the students to internalise those structures and processes that constitute the public world of the classroom.

THE COMPONENTS OF KNOWLEDGE ACQUISITION IN THE CLASSROOM

In this section, I will identify, from the classroom data from Study 4 (a science unit on the weather) and Study 6 (an integrated social studies and science unit), those processes that are involved in the acquisition of curriculum knowledge. There are two sources of data that led to the identification of these five processes. The first is the interview data (described in the second section of this article) that shows that students construct and elaborate extensive networks of information during the process of acquisition. The example of Kim and the concept of a 'charter' suggested that whatever the processes are, they produce an elaborated and coherent network of interconnected ideas and information. The second source of data comes from the application of the model of learning described in the first section of this article. This analysis makes it possible to identify, for each student, those individual experiences that are implicated in the acquisition of each piece of information. The example of Joy learning that it did not rain in Antarctica illustrates this kind of analysis. Systematic analysis of these specific learning experiences suggested that there were five broad types of processes/activities involved (see Figure 5).

Insert Figure 5 about here

These activities/processes are not sharply defined because they do not occur independently of each other. Nor is the set of five likely to be totally inclusive. I make no claim, at this stage, to have identified all the activities/processes that might be implicated in knowledge acquisition. But the five that have been identified are comprehensive and general enough to suggest that, taken together, they constitute the underlying activities/processes by which students construct the coherent elaborated networks of knowledge that characterise their learning in typical science and social studies units.

I have used the term 'activities/processes' to represent the fact that they occur at the three levels of student experience: the public and the semi-private (whole class and small group social activities) and the private (cognitive processes), and that these three levels may occur simultaneously and interactively with each other. In the descriptions that follow, both the social and personal aspects of the activities/process will be illustrated, and in particular, the ways in which these activities/processes are shaped by the social and cultural dynamics of the classroom. Because the focus is on both the nature of the activities/processes and on the ways in which these activities/processes become internalised, it is important to understand that the social and cultural context of

the classroom becomes the content of what is being acquired. The reader needs to hold in mind that internalisation is the process of acquiring expertise through use. Examining how students engage in these activities/processes is to examine both how they acquire knowledge and how they acquire the means of acquiring that knowledge.

1. Acquiring and clarifying information.

Knowledge acquisition begins at the point when new information is brought together with old information already stored in memory. While curriculum resources and the teacher provide much of the new information, there are many contexts in which students are required, or will want to acquire new information for themselves. Searching for information involves skills and resources that are sometimes internal (e.g., searching memory) and sometimes social and cultural (e.g., knowing who, how and when to ask, knowing where and how to search). During class discussions, responding to a teacher's question, whether it is done publicly or privately, involves retrieving relevant information from memory. In a previous article I have described in some detail how students engage in the memory search process during classroom activities (Nuthall, 1996a). The following example, from Study 4, illustrates one aspect of this process. Pam, engaged in privately answering the teacher's question, cannot immediately recollect the answer and engages in a memory search procedure that is reflected in her whispers to her neighbour.

Teacher: What's it [a barometer] actually measuring? Its measuring something rather special

Student: Heat

Teacher: What measures heat?

Student: A thermometer

Teacher: So it's not a thermometer is it. It's a barometer.

Student: The weight of air.

Pam (whisper to peer): Oh, what do they call it. Something bars, bar ...

When a student is thought by other students to be expert in an area, the other students may request information from that student during a class discussion. In Study 6, both Joy and Paul had made a special study of the Emperor penguin, and whenever the class discussion was on that topic, they contributed both publicly and privately.

Leigh: How do they actually carry their eggs on their feet?

Teacher: On their feet. They must just sort of hop around a bit would they?

Paul: They do little waddles.

Teacher: Yeah.

Ben: (inaudible) on their feet so they take it off for their food.

Teacher: Right. So who gets the food?

Student: The female.

Teacher: Right. OK. It's a mutual partnership then isn't it? So he keeps the egg warm and she gets the food.

Joy (privately to Masako): It said that they hold it under the flap of their tummy.

Masako: Yeah. Yeah.

Cory (whispered to Paul): Males with what?

Paul: Eggs

Cory: Carry the eggs

Paul: Mm

Cory (to Paul): The female. The female pigs out.

Paul: (inaudible) the male goes and pigs out.

In a group task activity obtaining information becomes part of the social process of the group. This may be co-operative and involve the spontaneous sharing of information. On day 4 of Study 6 the students were engaged in the individual task of preparing a list of questions to ask the visiting speaker. From time to time they asked each other for information. Jim wanted to ask about the magnetic pole but had forgotten its name.

Jim (to Ben & Paul): What's that Pole um, what's that proper Pole called?

Ben: The South Pole.

Jim: No um, the actual ...

Ben: Magnetic ...

Tilly: Magnetic.

Jim: Ah, the magnetic ...

Ben: ... pole.

Jim: ... pole. I want to ask if she's been there.

Paul: The magnetic pole is not the South Pole. It's sort of, the South Pole's over here and the magnetic's over there.

Ben: Hey yeah. She's been to Antarctica (inaudible).

Jim: Right. And if she says 'yes' I'll say 'Have you been to the magnetic pole?

Ben, Tilly and Paul all contributed interactively to provide Jim with the information he wanted. Such co-operation depends, however, on the relationships within the group, and on the kind of information required. Although they were helpful to Jim in the previous example, the students in his

group had developed an antagonism to his habit of always borrowing paper and pens, and to what they perceived as his dependency on them for spelling. The following example, from the next day, illustrates the increasingly sarcastic responses Jim received when he asked how to spell a word. The word was 'Antarctica' and as Paul pointed out, the word was visible to Jim in several places around the room.

Jim (talking to self, but loud enough to be heard by the others): Oh! How do you spell that.

Koa: What?

Jim: That. Not the word 'that' but ...

Tilly: T-H-A

Jim: I said not the word 'that'. (to self as starts to write) A-N-T-A-

Koa: What do you want? The word 'Antarctica'?

Jim: Yeah.

Koa: A-N-T-A-R

Jim (to self as starts to write) T-A-R-

Koa: I-C-A.

Jim (to self as writes) T-I-A, I-C-A. Oops!

Paul: You look over there (gestures to wall, where word is printed)

Tilly: (inaudible)

Jim: Oh, shut up Tilly! ... I don't listen to dumb people.

Paul: ... and you look over there and you look over there, and you look over on the board.

Jim: If you don't shut up Paul ...

Paul (sarcastically): That's all the places you can really look unless, Jim, you look back at some of your worksheet and your homework sheet even.

Requests for information may become occasions for negotiating status and influence within a group. The following example is from Study 4. The students were outside, and each group was making a written record of the weather (wind direction, cloud types, etc.). Tui was writing the record for his group.

Tui (to Tim): What do the clouds look like, Tim? What do the clouds look like? What do the clouds look like? Want a hiding? Well, what do the clouds look like? What do the clouds look like?

Part of the process of obtaining relevant information is to know what to ask for, and how to ask for it. This is not just a matter of curriculum knowledge, but also a matter of what is acceptable within the group. In the following example from the same day, Tui based his question on the mistaken belief that the direction of a wind is named for the direction the wind is blowing towards. It is not clear

whether Tim was deliberately misleading Tui, or did not understand Tui's mistake.

Tui: Shit, I done it wrong. Wind. What way's the wind blowing? What way's the wind blowing, Tim?

Tim: What way's the wind blowing? That way.

Tui: The wind's blowing that way? That way's north? Eh? South? Eh? That's way's south? Eh? Eh? Tim?

Tim: What way's it coming from?

Tui: I don't know. It's going that way. It's coming from the north. Yeah.

In each of these examples, obtaining relevant information was both an internal process (memory search) and a social process. The kinds of requests that were made and the ways they were framed were both a function of the student's prior knowledge and a reflection of their relative status in the group within the context of the content area or type of activity involved. The information could be given and obtained co-operatively, or through inducements or threats. Obtaining information from other students requires skills both in formulating appropriate questions and in creating or sustaining an appropriate system of giving and receiving favors. Status can be established through having relevant knowledge, creating the impression of having knowledge that will be useful, or changing the nature of the task so that the knowledge a student has becomes valuable. Having relevant knowledge is connected to a sense of self-worth. A student who has relevant knowledge and understands how status is related to that knowledge finds engaging in classroom tasks more attractive than does a student who finds engaging in such tasks constantly demeaning.

There was evidence that knowledge could be traded as a commodity and exchanged for other knowledge or task-relevant commodities such as colored pens (Alton-Lee, 1984; Morine-Dershimer, Galluzzo & Tully, 1981; Cohen, 1984).

2. Creating Associative Links

A number of different theories of the nature of meaning claim that interpreting and organising new experiences requires connecting them to existing knowledge. For example, in schema theory, meaning is achieved by linking a new experience to an existing schema (Alber & Hasher, 1983; Derry, 1996). Lemke (1990), who takes an entirely different social semiotic position on the nature of what he calls 'meaning making activities' also sees the discourse of meaning making as the locating of new experiences within existing networks of meaning. Our data indicate that students frequently engage in the process of connecting

new experiences and new information to prior knowledge. Often these activities have the character of play, especially with new and unfamiliar words and ideas. In the following example from Study 4, the teacher was introducing the students to the names of the different types of clouds and writing them on the blackboard.

Teacher: This is the word (writes 'cumulus' on blackboard)

Student: Cumulus.

Teacher: Cumulus.

(writes 'nimbus' on the blackboard)

Student: Nimbus

Teacher: (writes 'cirrus' on the blackboard)

Student: Syros.

Student: Cirrus.

Student (to self): Nebulite windows.

Pam (to self): Numulus, nimbus. ... Oh yeah, nimbus.

Student 2 (to self): Nebulus.

Rata (to self): Curious

Pam was experimenting with the pronunciation of nimbus. Rata and the other student made connections to words they already knew. In the next example, from Study 6, it was the idea, rather than a specific word, that produced a playful response. The process was also a social one in which Ben and Paul played off each other's responses. They shared a mutual understanding and appreciation of the same use of words. The class was discussing a food chain and the teacher was writing the students' ideas on a chart.

Teacher: Right. Fish. What do fish, what do fish eat?

Carl: Little fish.

Maude: Fish food.

Masako: They eat little fish don't they?

Teacher: Little fish (writes 'little fish' on chart).

Jane : Big fish eat little fish and little fish eat littler fish.

Ben (whispered to Paul): Big fish eat little fishy. Little fishy's, little fishy's eaten by littler fishy.

Paul (whispered to Ben): And little fishy's eaten by big fish, by a bigger fishy, which is eaten by a bigger fishy (laughs).

These examples of playful associations and variations on new words and ideas raise interesting questions about the origins of these processes. At first glance they seem to be unrelated to the serious business of the classroom, generated by some inner need to play with new ideas in the same way that a very young child seems to have an inner need to engage in pretend play and playful imitation of significant social activities. There are, however, classroom tasks that encourage, if not require, such apparently spontaneous activity. An excerpt from a brainstorm that occurred near the beginning of the unit on weather (Study 4) illustrates this. Tui's group was generating and recording a list of weather words. The teacher had set the task up as a competition between groups for the longest list. Tui carried on a running commentary as another student wrote words on the group's list.

Tui: Sunny. We've got sun, yeah, but sunny?

Student: That's to do with sun.

Tui: Muvver, muvver, wevver, wevver, weather. ... So we got all of them. Stick one here at the top [of the page], at the top, at the top. ... damp, damp, dump. ... doo, doo, black, black ... (inaudible). Ice, ice, icey, iceblock. Tornado. We've got tornado, potato, squashed potato. ...

For all its playfulness, such word-play was a useful strategy for generating more words related to weather. Such brainstorms provide the conditions in which students can practice, overtly or covertly, memory search activities. In the next example (from Study 4), the students cued each other's associative responses.

They were working outside the classroom, observing and recording the type of clouds they could see.

Student 1: Clapa nimbius aren't they?

Student 2: Crackanimbus? What are you talking about?

Student 1: Catty limbius clouds

Student 2: Columbius.

This kind of word-play flows over into what might be called concept-play. In the next example (from Study 4) the students were working together to produce descriptions of different weather patterns on a large sheet of paper.

Mary: No, it's not snow.

Glen: Doesn't snow in New Zealand.

Jan: It does not.

Glen: Not in Christchurch.

Jan: It only snows in the mountains.

Glen: And Mount Cook.

Jan: Yeah.

Glen: And Mount Egmont and Mount everything

Jan: Mount Egmont I love. I've been over there. I've got a T shirt of Mount Egmont.

Glen: Mount Tekapo?

Jan: Yeah.

Glen: I suppose that is.

Jan: No. And there's, um. ...

Mary: It just about snowed the other Friday. Last Friday. That was thick cloud.

Jan: The clouds are, um, ...

Glen: Sheep clouds.

Jan: Yeah. Sheep clouds, all puffy sheep clouds. Baa lamb clouds.

The students, as a group, followed the associative links that came to mind. Taken together, their responses were the product of the collective mind of the students as a group.

Tasks and resources may be structured so that they cue or invite students to identify relevant associations. In the next example, the teacher (Study 4) had asked the students to compare two weather maps copied from the local newspaper. Pam noticed the key to the map symbols printed on the bottom of the map and read them to herself, during the discussion.

Teacher: So you could say that the 'H' in Map A has moved across a bit?

Student: Yep.

Teacher: Would that be fair?

Student: Yes.

Teacher: It looks like it's moving across?

Student: Yes.

Teacher: OK. and there's an 'L' comes in that wasn't there before.

Pam (reading to self): It's low pressure or depression.

Pam (to self): It's not as big.

Pam (to self): It's low pressure or depression.

Earlier, Pam had made another important connection with the weather maps. At the time the teacher announced he was going to hand out the weather maps, she made a connection with her own personal experience.

> Teacher: I'm going to give you two for each group. All it is is today's weather map from The Press. That's all it is.
>
> Pam (whispering to peer): I go to The Press [printing works] every day 'cause that's where my father used to work ...

In the next example (also from Study 4), Rata made the connection between the thermometer the teacher was talking about in class and the one her brother had at home.

> Rata: I like putting my hand on my brother's one. Putting my hand on the bottom and it [the mercury] goes up.
>
> Student: Does it?
>
> Rata: Yeah. I like doing that. We've got one at home and its got the button like that, and I like putting my hand on it, and it goes up more.
>
> Student: Does it?
>
> Rata: Yeah. We've got one about that big, and it's got a tiny wee thing. I like putting my hand on it.

Like Jan, Rata does more than just make the connection. She shares it with a peer by telling a story about her brother's thermometer. In this way the two students weave together their own experiences with their classroom experience so that the two become increasingly entangled with each other. These entangling narratives include stories that the students have heard as well as their own personal experiences. The next example (from Study 6) was a private discussion between Joy and Jane that occurred during a transition between activities soon after the class had been discussing frost-bite.

Joy (to Jane): I know this man, I don't know him but (inaudible) and he got frostbite and a boil on his, you know, on his foot and they had to, had to string his foot back on, just on the bottom of his foot.

Jane: (inaudible)

Joy: He got frostbite or something, and the bottom of his foot came off, and they put string round it to keep it on.

Jane: Oh, yuck!

Joy: It was (inaudible).

Other researchers have identified 'relating information to prior knowledge' as a cognitive strategy that students report using frequently during instructional activities (Peterson, Swing, Braverman & Buss, 1982; Winne & Marx, 1982). One of the major effects of creating such relationships is that the new information inherits the characteristics of the existing knowledge structures. For example, as Rata made the connection between the thermometer in class and her experience of her brother's thermometer at home, she attributed the characteristics of her brother's thermometer (when you put your hand on 'the button like that ... it goes up more') to the class thermometer.

That students frequently share such associations means that a class, or groups of students within that class, must progressively build not only networks of associations within their own minds, but also networks of associations between each other's knowledge and experiences. This creates a network of many different 'distributed' knowledges in which each student participates to a greater or lesser extent, depending on their membership within the different interacting groups within the class (Lave, 1988, 1991). These might best be described as small knowledge communities developing within the larger class-wide knowledge community.

3. Elaborating the Content.

The third general knowledge acquisition activity/process involves the development and elaboration of information by making relevant inferences, identifying implications and logical extensions, and dealing with any contradictions or confusions that these create. During teacher-led class discussions such elaboration is usually structured by the kinds of questions that teachers ask, and the way they respond to student answers. Detailed analyses of the way teachers use questions and subsequent comments to structure student responses have been carried out by several researchers, often for the purposes of identifying 'higher-level' thinking in the classroom (for a review see Redfield &

Rousseau, 1981). The following brief excerpt from a teacher-led discussion on the 2nd day of the unit on Antarctica (Study 6) illustrates the way in which teachers typically engage students in the elaboration of content. In this example, the elaboration involves providing an explanation.

Teacher: OK. And what do icebreakers do that other ships can't do? Robin?

Robin: They break through ice.

Teacher: OK. Break through ice. Why, why can they break through, why can they and not other ships? Jill?

Jill: Um, they've got like a special wheel that goes down and chews through the ice and the other ships all (inaudible) special (inaudible) and they just (inaudible).

Teacher: Right. OK. ... Colin?

Colin: Icebreakers have specially designed bows, um, strengthened so they can plough through it.

Teacher: Excellent. OK. So they're specially designed. Just what you were saying Jill. OK?

As students acquire facility engaging in such discussions, they adopt the same activities/processes themselves. The following examples illustrate the range of these activities/processes and the ways in which their use in the classroom is shaped by the social and cultural context. In the first example, the process is one of inference, exploring a hypothetical possibility. The students in Jim's group (in Study 6) were developing questions to ask a visiting speaker. They were considering what it would be like to work in such extreme conditions.

Koa: They wear such weird clothing.

Jim: You want, all right, if you go there, would you wear woollen underwear?

Koa: What?

Jim: If you went there, would you wear woollen underwear? I wouldn't.

Koa: What?

Jim: I wouldn't. I mean I would.

Koa: Wool irritates my skin.

The task of preparing questions to ask a visiting speaker required the students to imagine what it would be like in Antarctica so that they could ask appropriate questions. For Jim this meant trying to understand what clothing you would have to wear and what it would feel like. Although the discussion is incomplete, Jim and Koa shared the task of inferring what it would be like to be in Antarctica. For this reason the process of inference also involves establishing mutual understanding of each other's logic. Jim interprets Koa's 'weird clothing' as 'woollen underwear'. Koa fails to understand this connection ('What?', 'What?') until the end ('wool irritates my skin').

In the next example, taken from the next day after the visiting speaker had talked about her work in Antarctica, the group was discussing the tradition among New Zealand Antarctic workers to swim, with nothing on, in Lake Vanda. The visiting speaker had told the class that if a worker did not go for the swim, she/he was required to sign a book acknowledging cowardice.

Paul: Jim, what would you do? Sign the book or go skinny dipping?

Ben: Sign the book.

Paul: Would you really?

Ben: Yeah.

Tilly: (inaudible) Antarctic water.

Ben: But you'd have to get your head under the water.

Tilly: (inaudible) but you'd be a lot older, to get it.

Ben: I know, but I'd still sign the book.

Paul: I'd just dive in and quickly climb back out. That puts your head under.

Nell: I wouldn't even do that.

Paul: Hey, you only have to get your head wet. Tilly. Tilly. You only have to get your head wet.

Ben: You have to go totally under you see.

Paul: Yeah. You just dive in.

Tilly: I'd dive in, get out.

Ben: I find it hard enough to get into a heated pool so I'd just (inaudible)

Tilly: Oh, I don't know about that. I dunno.

Paul: I'd get my badge.

As they explored the implications of going swimming (how would you do it, what would it feel like, etc.), their discussion was structured by their personal relationships and their sense of their own courage. Paul asserted bravado. Ben acknowledged his fear of swimming. While the logic of this discussion was about what it would be like if you went swimming with nothing on in sub-zero temperatures, the implications were as much about each student's sense of self-worth and relative status as it was about appropriate inferences.

In the next example, the students were trying to develop an explanation. The teacher (on Day 2 of the unit on Antarctica) had asked the students to prepare a list of questions that they would like answered during the unit. As they prepared their questions, many of the students started thinking about and discussing the probable answers to their questions.

Koa: Does anybody know anything about why Antarctica's so cold?

Jim: Because of all the ice.

Koa: How did the ice get there?

Paul: It's at the South Pole because it's the furthest point away from the sun.

Jim: It's the furthest ...

Ben: It's at the Pole.

Jim: It's the furtherest ...

Ben: It only has the sun for part of the year. It's got big long periods and short periods and so it hasn't got a chance to keep on heating up and stop for a while and heat up ...

Jim: It has very very short days during um, spr ...

Ben: It doesn't have any days during winter. ... etc.

This discussion mimics the typical teacher-led discussion. It was initiated by Koa asking teacher-like questions. The construction of the explanation required by the questions was a group process, with each student contributing according to his own understanding. It is another example of the creation of 'distributed' knowledge, in which each student acquires part of the explanation from others. Wells (Wells, 1994; Wells & Chang-Wells, in press) has suggested that the interactive structure of the typical teacher-led class discussion creates a Vygotskian zone of proximal development within which the teacher contributes to the increasing skill of the students in elaborating their own knowledge. The teacher 'steps-up' the quality of the students' responses. In this example, the students created their own zone of proximal development in which the role of expert (taken over from the role of the teacher) shifted from student to student as they mutually contributed their own knowledge. The significance of the exchange of expertise between students in changing student beliefs has been demonstrated by Miller (1987) in a series of studies of the effects of argumentation among groups of students.

That students take on the role of the teacher and replicate the structures of teacher-led class discussions is further illustrated in the next example. The context was a teacher-led brainstorm in which the class were listing the things they knew about Antarctica (Study 6). Ben made his contribution to the public discussion, and immediately afterwards Jim engaged him in a private discussion about his public response.

Teacher: Ben?

Ben: Some people live underground there.

Teacher: Okay. (writing on blackboard)

Jim (privately to Ben): You can't live too far underground otherwise the water seeps up.

Ben: It doesn't ever melt though.

Jim: Yeah but ...

The effect was an elaboration of Ben's public response that was constructed between Ben and Jim privately, in parallel with the continuing public discussion. Implicit in this private discussion is a disagreement between Jim and Ben about the effect of ground water. Much of the elaboration of information that occurs between students occurs in the context of uncertainties and disagreements about information or its implications. The following example occurred when the students were creating a list of the kinds of work that people do in Antarctica. Jim suggested 'guide' but Ben claimed it was identical with the work of an 'expedition leader' that they already had on their list.

Jim: Um, guide, guide.

Ben: It's kind of like a leader?

Jim: No, cause the expedition leader is a leader. He just, the guide knows where everythink is. The expedition leader doesn't. ...

Ben: An expedition leader has to know where everything is as well or else he wouldn't be an expedition leader, 'cause he's supposed to guide them all around the place and tell 'em where to go.

Jim: Yeah.

Ben: He's the most experienced and therefore he should be the guide.

Jim: Yeah, but first of all they'd need a guide that's been there. While he's learning ...

Ben: Well, he wouldn't be the leader while he was learning.

Jim: Yeah.

The task of creating a list generated, through disagreement, an elaboration of the qualities of an 'expedition leader', each student drawing on their prior knowledge of what would be involved in being a leader. Implicit in this activity is their belief that their responses should be justifiable, and that providing a justification is a required activity. Such an expectation forms part of the developing culture of the classroom. The logic and forms of knowledge, or genres, relevant to a specific curriculum area, are also part of what is being internalised as students mimic, practice, and become expert in these activities/processes.

The importance of these cultural forms becomes apparent when students use other ways of negotiating disagreements. Such disagreements can range from an informal exchange of differing beliefs to hotly contested and occasionally aggressive debate. In the next example the disagreement is overt, and the justification given is itself debated. The students (in study 4) were engaged in making a list of words associated with the concept of 'weather'.

Student: Leaves.

Pam: Leaves are not part of weather.

Student: 'Tis so

Pam: It is not.

Student: Leaves roll on the ground.

Student 2: Wind blows them.

Student: Winter makes them brown, you fool.

Pam: But that doesn't make weather.

Student: Want to bet? ...

Behind a debate of this kind lies an implicit set of criteria for deciding what counts as a justification. In the previous example about an 'expedition leader' Jim agreed that Ben's argument was true ('Yeah'). Consequently, he came to agree with Ben, and his word ('guide') was not included in their list. In Pam's group, no such agreement emerged. Instead the competing student issued a challenge ('want to bet'). Such a challenge was an assertion of authority, irrelevant to the logical content of the discussion, that challenged Pam's commitment and right to assert her point of view. It implied that being right is a matter of assertion and status, rather than evidence or truth. Betting is a cultural ritual and in this context was an interesting example of the way culture, and the social dynamics of the student relationships, became part of the content of the students' knowledge.

Debates about curriculum content are themselves sociocultural forms. Students sometimes engaged in debates or arguments for the sake of the argument rather than for the sake of deciding what was true. In the following example (from Study 4), the students were outside the classroom, recording the day's weather.

Pam: What's the clouds like?

Student: Nimbus. Nimbus.

Pam: It is not. Look! Clouds aren't nimbus.

Student: They are so. Look!

Pam: What is nimbus, anyway?

Student: Big black. They're big and black

Pam: Oh, you are [black]!

Student: Big black rain clouds.

Student 2: Don't look like rain clouds to me.

Part way through the argument, Pam admitted that she didn't know what 'nimbus clouds' were 'anyway' and withdrew from the argument, salvaging some of her status by abusing the other student ('Oh, you are [black]!'). Such arguments can also be resolved by aggression. In the following example the group was engaged in the same activity, recording the day's weather outside the classroom.

The discussion was about the temperature reading on a thermometer. Tui was holding the thermometer.

Student (recording the weather for the group): What's the degrees?

Tui: Seventeen.

Student: No, it's not. (taking the thermometer)

Tui: Giz a look at that (reaching for thermometer). My eyes don't trick me.

Student 2: It's seventeen.

Tui: Giz it here.

Student 2: Oh, it's gone down.

Tui: Give it here or someone's going to get a sore mouth.

Student 2: It's sixteen now.

Tui: Hold it up straight.

(This argument continues for the next half minute)

Tui: It's seventeen. That's fifteen there (pointing to scale on thermometer), so that's sixteen, and that's seventeen. OK? Got it?

Student: It's fifteen.

Tui: Get stuffed. (starts singing) Da da de de didi de ....

Implicit in the two previous examples is the belief winning an argument about what is true creates or sustains social status. The elaboration of the content that occurs during these arguments is structured by the different cultural forms of argument, and is simultaneously part of the knowledge elaboration process, part of establishing what counts as true or valid knowledge, and part of the social process of establishing and maintaining status and role.

Other cultural forms or genres are used by students in the elaboration of information. In the following example, from Day 4 of Study 6, the students were preparing questions to ask the visiting speaker. Nell asked the others in the group whether you could grow food in Antarctica and the discussion moved to the frozen conditions.

Tilly: You'd have to eat ice blocks for tea.

Ben: Eh?

Tilly: Imagine having ice blocks for tea and eating them.

Ben (miming drinking tea that is frozen): Have a cup of tea. OK. Shuunk (imitating sound of frozen tea falling from cup).

Jim: Yeah. Have a cup of tea, well, we've taken the cup away.

(Jim and Ben mime taking cup away, dropping the frozen tea, and eating it)

Nell: An ice block of tea.

Jim: Have you ever had a block of tea for tea? ... Have you ever had a block of meat? Ben, imagine pouring gravy on um, meat!

After the visiting speaker had talked to the class the students had to write a report of what she had said. Jim wanted to know if she had been to the 'magnetic pole', but she had not mentioned it. A discussion developed between Jim and Paul about the magnetic pole.

Jim: Yeah. And you can get lost. You have to go by chopper. You have to go by chopper and then you get, and then the magnetic um, energy would kind of give you a down pull [gestures with hands], a down draught and you'd get in more trouble than its worth.

Paul: I don't think it's that strong, Jim.

Jim: No, but the, well look, if they can pick it up in America, then it will be quite strong. Quite strong. I mean it would interfere with the radio contact. If they took them in too close, by the chopper ...

Paul: Hey, Jim, Jim. What you do is you get down onto a sledge. You hold a magnet and you throw yourself off your sledge [makes screeching noise, mimes a sledge out of control]. Oh, slow down! Cause there's this massive pull.

Jim: So I went [makes crashing noise, also mimes out-of-control sledge].

Paul: No Jim. You go straight through the centre of the earth and pop back out at the magnetic pole at the North pole. Oh! This is the Arctic! Errgh! A bit hot, though. ...

Such imaginative stories involve the students in the co-operative elaboration of the new information and the integration of it into their own prior knowledge. The construction of the story is fun, and like other forms of play, is part of the way in which the students gain mastery over the new information. Like contributions to arguments, contributions to stories reflect the relative roles the different students play within the group. Status and cohesion are reinforced and woven into the curriculum content.

The examples given above of the activities/processes by which students elaborate curriculum content illustrate the ways in which students replicate the structures of teacher-led discussions, and make use of the structures of arguments, jokes, and story-telling. As they do so, the social processes and structures of their interpersonal relationships are interwoven with the cognitive processes and structures implicit in the cultural forms that they use. Social status becomes truth. Explanations become jokes. The elaboration of information is developed through imaginative story-telling. All the while, a continuous process of elaborating and interconnecting concepts and experiences develops both the shared knowledges of the classroom and the individual minds of the students.

4. Evaluating the truth and consistency of information.

In the examples of elaboration described above, there was reference to the way arguments involved the interweaving of the dynamics of social position and status with evaluation of the truth and validity of information. The examples in this section will focus more directly on the ways students evaluate the consistency and validity of the information they experience or create. In the process of acquiring and elaborating knowledge, students acquire the ability to evaluate that knowledge and to detect consistencies and inconsistencies between different aspects of their experiences and beliefs. Essential to the acquisition and organisation of knowledge is the ability to tell what is the same and what is different, what is consistent and what is inconsistent, what is to be true and believable and what is not. This kind of evaluation is constantly present, implicitly if not explicitly, in the public and social dimensions of classroom experience. Teachers constantly evaluate all aspects of classroom life. To be a student is as much a matter of obeying the rules of classroom life as it is a matter of understanding the rules of relevance, coherence and truth embedded in the curriculum. Most of the time it is not possible for teachers or students to separate the two. In the following examples, I will try to sketch in some of the ways in which the 'evaluative climate' of the classroom (Doyle, 1986) permeates the public, the semi-private, and the personal dimensions of students' classroom experience.

Evidence from students' self-talk suggests that they acquire the practice of constant evaluation of their own and other students' responses and thoughts. For example, Rata (in Study 4) appeared to be constantly involved in evaluating her own and other students' responses. During a teacher-led discussion on weather prediction, she noted the apparent error in another student's public statement.

Student 1: The red sky at night is the shepherd's delight.

Teacher: Is it?

Student 2: It's a shepherd's warning

Teacher: Is it? Are you sure?

Rata (to self): Orange. The sun would be setting and the sun would be orange.

Several times Rata expressed delight and surprise at getting the right answer to the teacher's question.

Teacher: What's another word for [air] pressure? another way to explain pressure if we don't understand pressure? Rata?
Rata: How heavy the air is
Teacher: Simple as that. Did you hear what she said, Sue?
Sue: No.
Teacher: Say it again, Rata
Rata: How heavy the air is.
Teacher: It's the weight of air. What information can we use that tells us the weight of air? ...

Rata (to self): I got it right!

Rata (whisper to peer): I didn't even know that was right.

Rata expressed the same delight on another occasion without making a public response. The teacher was discussing a thermometer and Rata raised her hand to answer a question but was not noticed by the teacher.

Teacher: What is the silver stuff called? Does anyone know?
Student: Mercury.
Teacher: Is that right? It is called mercury. No question about that. Used to be called in ancient times quick silver. Why do you think it's called quick silver?
Student: 'Cause its got silver in it.

Rata (to self): Good. I got it right then.

Rata (to self): Cor, I got it right!

Her self-directed comment in this example is so similar to her comment in the previous example that it seems likely she was evaluating her own internal response to the teacher's question. What her private responses in these two examples also reveal is Rata's evaluation of her own ability. Rata was a high achieving girl. Her comments suggest, however, that she had a low or uncertain estimation of her own knowledge which she related to her ability to answer the teacher's questions. She found public confirmation of her responses surprising.

In the next example, Jim (from Study 6) shared his self-evaluation of his public response. The teacher was creating a list of Antarctic animals on the blackboard.

Teacher: Jim

Jim: Um, the killer whale.

Teacher: Good boy. (writing on blackboard).

Jan, what have you got?

Jim (glancing around group): Everybody knows that one (raising his eyebrows).

Jim was letting the others in his group know that despite the teacher calling him a 'good boy' they should not think of him as special ('everybody knows that one'). It would require a deeper analysis of Jim's role and status within his group to fully understand the significance of this shared self-evaluation.

It seems likely that internalising the evaluation practices of the classroom is a way in which students can gain some control of their own status in relation to the teacher and other students. Appearing to be a willing and capable participant in teacher-led class discussions may raise or lower status within a student's friendship and working groups, depending on the culture within the groups. Self-evaluation provides a way of preventing public mistakes and of managing the appearance of being a clever or willing participant in classroom activities. Evidence that we have reported elsewhere suggests that boys are more likely to over-estimate their own knowledge, and girls to under-estimate (Alton-Lee & Nuthall, 1992). Such gender related differences reflect the wider culture. The differences in the private self-evaluative responses of Rata and Jim, in the examples above, may well reflect these cultural differences.

Students internalise more than just the role of student in classroom activities/processes. They also internalise the role of the teacher not only in relation to each other, but also in relation to the teacher herself. For example, on Day 2 of Study 6, the students saw a video about Antarctica and the teacher followed this up with a discussion about the conditions in Antarctica. The students were asked to describe any information from the video that they found particularly interesting. Jane commented on how dry it was in Antarctica.

Teacher: OK. That the, that Antarctica is drier than the Sahara Desert. That might be a really interesting thing to find out. Why is it drier than the Antarctic desert? OK.

Paul (to Ben, whisper): She said, why is it dry as the Antarctic desert.

Paul's reference to the teacher's mistake ('Antarctic desert' instead of 'Sahara desert') reflects an expectation that neither teachers nor students should make

mistakes. Paul has internalised not only the role of the teacher as evaluator, but also the relative status of the one who can make such evaluations. In the next excerpt, Jim also identified a mistake he thought the teacher made when she discussed the 'food chain'. During this discussion, the teacher had built up a chart of the 'food chain' from the students' contributions to the discussion.

Teacher: OK. So we can put them into subdivisions. Alright. First of all, we'll start off and we'll go this side, from this side to this side [of the chart] and perhaps we should look at where, what the sort of meat we have and where it might come from. OK?

Jim (to self): This isn't a food chain. It's a tree. ...

Jim (later to Ben and Paul): (inaudible) that's, that's not a food chain.

The evaluative comments by Jim and Paul in these two examples parallel Rata's continuous self-evaluation in the previous examples. While her self-evaluation was primarily private and internal, theirs occurred in the semi-private world of their immediate neighbours.

Some classroom activities involve more intense or consistent evaluation than others. When a student is required to write a report on behalf of the other students in a group, the student may be subjected to highly critical surveillance. The reputation of the group depends on the performance of the reporter. The following excerpt from Study 6 occurred when the students, working together in groups, were required to report on the similarities and differences they could find between two photographs of people working in Antarctica. Joy was asked to write the list of similarities and differences for her group.

Maude : They all have protective clothing on.

Koa: Don't ask, don't ask me how to spell that.

Paul: You're not writing it. She is. Huh!

Maude : All have ...

Koa: Warm protective ...

Maude: P - R - O

Joy (to self as she writes 'protective'): Whoops!

Maude : T - E - C - T - I - V - Protective- E

Joy: Yeah ... What's different? Cause we've got six of them [similarities].

Paul (reading what she has written): They all have warm protective. They all have warm protective. You forgot 'clothing'. You forgot 'clothing' (everyone laughs).

Joy: Warm protective (laughs).

Paul: Um, it's C - L - O -, not cloting.

Joy: Oh don't worry. I know what it is.

Paul (reading what she's written): Colting, colting.

Joy: Oh well, I'll just leave it like that.

Paul: No, colting.

Maude: It's 'colthing' cause that's a T - H.

Paul: So, you could say 'colting'

Joy: Has this got snow or ... etc.

During this activity, Joy was exposed to constant evaluation of her writing. The others were aware of the difficulties (Koa: Don't ask me how to spell that), but laughed at her mistake. In the following excerpt, from the discussion in another group in the same class, the students indicated their awareness that Teine was too critical of others and welcomed an opportunity to find a mistake in her spelling.

Teine: Is that your rough copy? (Leigh nods) Oh, I was gonna say! Ooh, ooh, he can't even spell (gestures to Colin).

Cory: Who?

Teine: Colin. He can't spell 'penguin'. He goes P-E-G- U-N-I

Leigh: Teine, some people aren't good at spelling.

Teine: OK. I shouldn't have said it in front of you.

Leigh: I know that.

Cory: Teine, you think you're good at everything.

Nathan (to Teine): You spelt "penguin" wrong. You forgot to put in the "N"

Leigh: Hah!

Teine: P-E-N-G-U-I-N then. Yes.

In general, it is the evaluative process embedded in public class discussions or activities that provide students with the criteria for judging their own and other's activities. The teacher is the major source of these criteria. In the following example from Study 4, the teacher was listing on the blackboard the words about weather that each group had recorded from their previous group discussions. In Pam's group there had been an unresolved discussion about whether 'muddy' was a word about weather.

Teacher: Ned?

Ned: I've only got one and that's ... muddy.

Teacher: (writes on blackboard) Muddy.

Ned: Icey.

Teacher: Icey. We've got icey somewhere [on the blackboard], haven't we?

Student: Yes.

Pam (whispering to peer): Oh, that's not weather.

Student (whispering to Pam): See, I told you it was a word. See. See. You never listen.

The teacher's acceptance of 'muddy' was used by the student to resolve her argument with Pam. As other researchers have found, in the traditional classroom the teacher is the major source of the criteria for what is right and what is relevant (e.g. Frid & Malone, 1994, April). Consequently, students must learn to interpret the teacher's evaluative comments if they are understand and internalise both the explicit and the implicit criteria that the teacher uses to judge their activities. In the next example, Rata was concerned that each day her group was recording the weather, they reported the wind speed as 'moderate breeze'.

Student: It would be a moderate breeze.

Rata: Don't write anything out, 'cause we've got to check it. Don't write. Don't write anything. Don't write 'moderate breeze' all the time.

Student: Well, you write it.

Rata: Don't write 'moderate breeze' all the time. We shouldn't write the same thing all the time or we'll get in trouble.

Student: What?

Rata was aware that if their daily reports were identical, the teacher might not believe that they had actually observed the weather. Her concern was not about 'moderate breeze' as a valid description of the wind speed for that day but about the criteria the teacher was likely to use when he judged the group's work. Interpreting the mind of the teacher is part of the process of coming to understand and consequently to manage the evaluative climate of the classroom. If internalisation is the process of becoming expert in the activities of the classroom, and becoming an expert involves understanding the mind of the teacher, then internalisation implies (in the examples described above) becoming like the teacher.

Although it is the general thesis of this article that, as students participate in the activities of the classroom, they internalise the structures of those activities, the process is not one-way. In the next example, there is a clear disparity between the way a student's response is evaluated by the teacher and the way it is

evaluated by another student. In this excerpt, the teacher was leading a discussion in which the students were reporting what they had found most interesting in a visiting speaker's talk. The teacher was asking each student in turn to report to the class. Lapana was a student from an ethnic minority who had rarely spoken publicly in class. When it came to Lapana's turn to contribute to this discussion, the teacher provided him with a prompt.

Teacher: Right, excellent. Lapana?	
Lapana: Um, I dunno.	
Teacher: What did you think of the clothing? Did you think that they would have to wear so much clothing?	Teine (to self) Oh ... dick! Stupid idiot!
Lapana: Yeah.	
Teacher: You did? You thought that they would have to wear all that gear?	Teine (to self): Doesn't even know!

Teine's private evaluation of Lapana's contribution to the class discussion was very different from the teacher's. Teine's comment related to the dynamics of interpersonal and inter-ethnic relationships between students in that class, and while she might have been aware of how the teacher was evaluating Lapana's participation, her evaluation reflected deeper social and cultural processes than those of the teacher-led discussion.

The above examples suggest that the evaluative structures and processes of the classroom are continuous through the public and private worlds of the students. Evaluating others and evaluating oneself are not distinct processes. The culture of the classroom is one where the uses of knowledge and the sustaining of status involve the same processes, so that evaluating knowledge is interwoven with evaluating self-worth.

5. Developing metacognitive awareness.

Part of the process of becoming an expert in classroom activities/processes is an increasing awareness of the components and structural relationships that constitute these activities/processes. One of the components of these activities/processes is the state of the student's own knowledge and thought processes. Evidence for an emerging awareness of their own thinking and knowledge occurs in the self-talk of students as they engage in these activities/processes. It also occurs in the semi-private talk between students

during small group activities. As a consequence, this developing awareness becomes caught up in the social dynamics of the group activities. The following is an example (from study 4) of a student expressing awareness of the status of her own knowledge. The teacher was leading a discussion of the way in which a compass works.

Teacher: What's it going to do for us, Lara?

Lara: It tells us what is north, east, and south and west.

Teacher: How does it do that, therefore, Noel?

Noel: Its kind of like a magnet.

Pam (whispering to peer): I know how it works. My father's got one. I mean my mum's father.

Pam had apparently decided that she knew about the compass and subsequently took little notice of the following discussion. She made the same judgement about the barometer when the teacher discussed it two days later.

Teacher: Because we have these machines [barometers] here. This is a school one which has unfortunately been messed up by somebody

Student: I've seen that

Teacher: It has got on it a little hand ....

Pam (whisper to peer): I know how these work. My grandad's got one of those.

In fact, Pam had little understanding of how the thermometer and the barometer work. Her idea of 'knowing' was different from the teacher's and limited the way she attended to the teacher's explanations. Her comment also served to increase her status with her peer. She claimed not only to have a thermometer and a barometer at home, but to know how they worked.

Teacher's often ask students to evaluate their own understanding of the material being talked about. In the following example (from Study 6), the teacher had been explaining how the students were to create their own food chain. Joy responded with an evaluation, but only to herself.

Teacher: All right? So you're trying to make food chains. Do, do you understand?

Joy (to self): Sort of.

Being aware of your own mental processing makes it possible to judge how easy or difficult a task is. In the following example from Study 4, the students were engaged in the task of predicting, from the data in the day's weather map, what the weather would be like next day. Only some of the students (including Rata) seemed to be aware that the task was actually almost impossible.

Rata: See. Anticyclone, high, it's coming onto New Zealand.

Student: So there's an anticyclone.

Rata: Oh, God, this is hard.

Student: There's a big cold front coming.

Rata: Oh, God, there is too. Look, there's a big cold front coming through Sydney. See, you can tell cold. See that shape of it.

Sometime later while the group was still engaged in the prediction task, Rata again expressed her sense of the difficulty of the task.

Student: We are going to have an anticyclone.

Rata: Oh, you wouldn't know what it's like tomorrow. It could be sunny tomorrow. It could be cold. It could rain.

Student: This is today's weather map.

Rata: Yeah, I know. But we've got to do it. What tomorrow will be like. We've got to do what tomorrow's will be like.

Unlike many of the other students, Rata tried to focus on all the details in the weather map, and struggled to make sense of their implications. Her judgement was based on an awareness of the relationship between the nature of the task and her sense of her own abilities and knowledge

How this self-awareness becomes entangled in group processes and status is evident in the next example (Study 6). The students were engaged in preparing questions to ask the visiting speaker. Jane was talking about how many she had already written. Joy was struggling to think of any.

Jane: I'm up to question number ten now.

Joy: I've got one (pretends to write) ...

Joy (writes a word and crosses it out, talks to self): I can't think of anything. (looks over at Masako's work and starts to discuss it with Masako)

Later Jane tries to help her by suggesting that she look at questions on the wall.

Jane: There's all those questions up there too that you could ask. You could ask them again. ...

Joy (to self) I know one ... (head on hand, leans over on desk, gasps when teacher says 'Just two more minutes', etc.)

Joy (to self): I can't think of anything (drums fingers on desk) ... (turns her piece of paper over and refolds it) ...

Each time Jane talked to her, Joy replied that she had one question. In fact she had written none. Her self-talk suggested that she was acutely aware that time was slipping by and she could think of nothing to write. Her status in relation to Jane and Masako was clearly at risk.

There were not many examples of this kind of self-awareness in our data. However, as the examples described above indicate, there were sufficient to give a sense of how students were aware of their own mental processes and shared these with other students within a context in which claiming to know, to understand, or to find mental processing easy, was a claim for a superior status.

SUMMARY AND CONCLUSIONS

What I have attempted to do in this article is to describe how students acquire and develop, through their participation in classroom activities, those cognitive processes that are involved in the acquisition of curriculum knowledge in typical science and social studies units. In the first section I described a model of knowledge acquisition that has been successful in predicting, through an analysis of the timing and content of students' content-relevant experiences, exactly what curriculum content students will, and will not, learn and remember. This model is based on the assumption that students have a working memory in which incoming experiences are integrated with existing knowledge and transferred to a long term store. What is not clear in this model is exactly what happens to incoming experience as it is converted into more or less permanent knowledge.

In the second section I described what it is that students must do with new information to translate it into knowledge. The dispersed and fragmentary nature of relevant experiences in the classroom means that the mind must be constantly engaged in identifying, sorting, and organising information relevant to many different concepts and ideas simultaneously. Evidence from students' recollections of their classroom experiences and the ways in which they recall curriculum content suggests that the product of this constant sorting and organising is an extensive and elaborated network of inter-related knowledge constructs.

In the third section, I described the theory of internalisation as this has been developed in the research of Piaget, Vygotsky, and others working from within related research perspectives. Within the context of the classroom,

internalisation occurs as students gain expertise in, and control over, the activities involved in knowledge acquisition. It takes place though the transactional relationship that exists among the three worlds that students inhabit: the public world of teacher-led discussions and teacher-organised group activities, the semi-private world of student-to-student social interaction, and the private world of internal cognitive processes.

In the fourth section, I identified a set of five activities/processes that, taken together, constitute the ways in which students acquire knowledge. There is evidence that each of these occurs simultaneously within each of the three worlds that the students inhabit. Within each world the way the activity/process occurs is shaped by the structures and dynamics of that world. Because of the transactional nature of the relationship between them, the structures and dynamics of the three worlds are constantly influencing each other. This means that, for example, evaluating information is an activity/process that is as much social and cultural as it is cognitive. It is not only structured by the logic embedded in the curriculum but also by the structures of social and interpersonal relationships embedded in the wider culture and being worked out in the social dynamics of the classroom.

Assumptions about knowledge and mind

Arising out of this account of how students acquire the processes of knowledge acquisition are a number of implications about the nature of knowledge and of mind. The first is the implication that knowledge carries with it its own means of understanding and interpreting experience. Knowledge is as much process as it is a substance (Alexander & Judy, 1988). Having knowledge is as much the process of engaging in acquiring, sorting, connecting, inferring, reorganising, using and reusing information as it is possessing some kind of knowledge object (Lemke, 1990). Part of the evidence for this view is that not only do students acquire knowledge acquisition processes through engaging in classroom activities, but they also 'acquire' a socially distributed network of knowledge. In the same way that a student's mind comes to contain an extending internal network of knowledge within which knowledge acquisition and organisation processes operate, so too does the classroom come to consist of a network of shared knowledge within which knowledge acquisition activities are carried out. The internal and the external mirror and imitate each other. They continuously interact as individual students contribute both to the shared knowledge and to the carrying out of socially structured knowledge acquisition activities. The students' internal knowledge and knowledge acquisition skills are

themselves changed by the ways in which this distributed knowledge and these social activities change and develop.

The second implication concerns the nature of mind. All the evidence available from our data, and from the conclusions we have been able to draw from this data, points to the view that the mind of the student is a complex system in which many different processes occur simultaneously. This is a view that is consistent with the views of philosophers of mind such as Dennett (1993). It is also consistent with the position taken by the Leont'ev (1981) and by Bakhtin on the nature of mental processes (Wertsch, 1991; Fernyhough, 1996). To the extent that an individual is expert in a social activity, the individual must know and understand the roles and activities of other possible participants. When students internalise the activities/processes of the classroom, they internalise the roles and activities of the teacher and other students. The mind becomes not an internal version of a single actor carrying out a single role, but an internal version of a community of actors interacting with each other according to their socially constructed roles. Expertise involves internalising multiple perspectives and multiple roles.

Because the social world is a constantly changing and evolving world, lacking the certainty and predictability of the physical world, the process of internalisation most also be continuous and constant. The way a student is exposed to curriculum content (see Figure 2 above) makes it clear that a student's mind must be tracking the evolution of many different concepts and ideas simultaneously. This suggests the existence of multiple working memories. However, the student cannot be simultaneously aware of the ways these working memories are constantly identifying the implications and connections between new experiences and previous beliefs and knowledge.

The internalisation of knowledge acquisition processes that has been described in this article is about furnishing the knowing mind as a whole, with all its complex array of parallel processing (Fernyhough, 1996). Consciousness, and those areas of mental processing that are in the direct control of the individual, must represent a very small segment of the whole continuously active multi-layered mind.

This view contrasts with the standard view that knowledge acquisition is a relatively simple and low level type of learning. If the analysis reported in this article demonstrates nothing else, it should demonstrate that having continuous detailed data from multiple sources about the classroom experiences of individual students uncovers an extraordinarily complex world that we need to understand if we are ever to learn how to manage that world effectively.

Questions of evidence and validity

There is an important question to be asked about the use of evidence and the status of the conclusions reached in this article. To what extent can data obtained from small samples of students from only five classrooms be used to reach general conclusions about fundamental aspects of the way classroom experiences shape students' minds? The first point to make is that this article is about building up a picture of how knowledge acquisition occurs and how students acquire the processes that generate new knowledge constructs. It reaches conclusions that are consistent with the data, not conclusions that are, in any sense, proved by the data.

However, it is based on 'hard' data that came from the development and application of a model of classroom learning. This model provided formal procedures for predicting, with considerable accuracy, student performance on extensive outcome tests (Nuthall & Alton-Lee, 1993, and Table 2 above). It also provided the framework that directed, and focused, the exploration and analysis of the less formal data.

Many of the claims made in this article have been based on the use of excerpts from extensive recordings, observations, and interviews with students. In particular, extensive use has been made of the recordings of self-talk and semi-private talk made from individual broadcast microphones. This self-talk and semi-private talk has been used as evidence of the existence and nature of the private, internal processing of information taking place in the minds of students.

The use of this data has been based on the premise that private cognitive processes become overt (observable in self-talk) in conditions where it is either safe and/or advantageous for the speaker. In the classrooms we have studied we have recorded high levels of self-talk and semi-private peer talk (Alton-Lee, Nuthall, & Patrick, 1993). This may be partly because the methods of recording we have used have been intensive, continuous and detailed, and partly because the classrooms we worked in provided the conditions for more self- and semi-private talk to occur. In Study 6 for example, the teacher frequently encouraged students to talk among themselves. She got the students to engage in small-group brainstorms before conducting whole-class discussions. Small-group tasks were a common. As a consequence the students were familiar with talking among themselves.

Research on self-talk among students indicates that its occurrence is sensitive to context (Behrend, Rosengren, & Perlmutter, 1989). There are classroom contexts in which it almost never occurs and there are classroom contexts in which it occurs frequently. However, the analysis reported in this

article is not about the frequency with which self-talk and peer talk occurs. Internalisation is not a function of talking. Internalisation occurs as students become more expert in the activities/processes involved in knowledge acquisition and become increasingly aware of the way those activities/processes work. Where self-talk and peer talk occur, they provide a window on the internalisation process.

For this reason, the conclusions reached in this article must be seen as based on fragmentary evidence. The validity of the conclusions depends on their consistency with the evidence obtained from the variety of different sources (interviews, recordings, observations), their consistency with the 'hard' data obtained from the predictions of what the students did and did not learn, and the intensive individual nature of the data base.

Designing the classroom as a community of learners.

I claimed at the beginning of this article that teaching is an art that depends for its success not only on the creativity of the teacher but also on the existence of an established body of knowledge about how students learn. The purpose of this article has been to expand our understanding of how students acquire knowledge in typical science and social studies classrooms. The view of knowledge and knowledge acquisition processes/activities developed in this article has one major implication for classroom practice. It is that students do not just learn the curriculum content they are exposed to in classrooms, they learn their total experience in classrooms. Not only do they learn the activities that teachers organise for them, they internalise the enactment of these activities within the larger cultural context in which the classroom is embedded. To the extent that students' minds are engaged by all the things that happen in classrooms, to that extent are their minds furnished by those experiences. To see student learning through the lens of the curriculum is to miss most of what is important in students' learning experiences.

The research reported in this article is part of the growing body of research that increases our awareness of what is significant in students' classroom experiences (Nuthall, 1996c). It brings into focus the over-riding significance of the of the social and cultural contexts within which classrooms operate. There is a now growing body of research on redesigning classrooms from the perspective of the classroom as a learning community (e.g. Wells & Chang-Wells 1992; Brown & Campione, 1994). The purpose of designing learning communities is to integrate students' interactions with the curriculum with their interactions with each other and the teacher, so that their entire experience contributes to their

development as intelligent learners. We now need to extend the design of classrooms as learning communities to incorporate the effective management of the five knowledge acquisition processes/activities identified in this article. Recent research on designing scaffolded learning environments and training children to create their own questions and explanations (e.g., King & Rosenshine, 1993; King, 1994) suggests how this might be done.

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Table 1. Characteristics of the units and the individual students observed and interviewed

Topic of unit and hours of recorded time per student	Students (gender)	Age (years)	Achievement (percentile)[a]	Interviewed after: 3 weeks	Interviewed after: 12 months	Item files
Study 2. The Middle Ages in England (52.4 hours over 21 days).	Amy (f)	9.9	93	√	√	100
	Kim (m)	9.8	30	√	√	99
	Sam (m)	9.6	14	√	√	97
Study 3. New York: A study of cultural differences (6.4 hours over 5 days).	Ann (f)	12.5	55		√	82
	Mia (f)	12.4	96		√	83
	Jon (m)	11.8	97		√	81
	Joe (m)	12.2	55		√	77
Study 4. Weather: observation and forecasting. (7.1 hours over 8 days).	Rata (f)	10.4	68	√		64
	Pam (f)	10.4	21	√	√	68
	Jan (f)	10.4	70	√	√	59
	Tui (m)	10.4	11	√	√	58
Study 6. Antarctica: Conditions, people, animals, and plants. (13.4 hours over 6 days)	Paul (m)	12.2	89		√	261
	Jane (f)	11.5	83		√	258
	Joy (f)	11.10	70		√	267
	Jim (m)	11.9	56		√	255
	Teine (f)	11.4	34		√	230

[a] Average age-related percentile on at least 3 school school-adminstered PAT tests, including reading comprehension.

Table 2. The prediction of learning outcomes for the concept files (test items) in the unit on Antarctica (Study 6).

Student	Predict learned			Predict not learned			All items	Already	Other
	correct	wrong	percent	correct	wrong	percent	percent	known	items[a]
Jane	57	8	87.7	44	8	84.6	86.3	93	4
Joy	50	11	82.0	43	12	78.2	80.2	96	2
Jim	43	19	69.4	48	5	90.6	79.1	99	-
Paul	53	19	73.6	23	8	74.2	73.8	106	5
Teine	36	5	87.8	71	18	79.8	82.3	82	2
Totals	239	62	79.4	229	51	81.8	80.6	476	13

[a] Other items includes those that the student failed to complete, or the answer was ambiguous in some way.

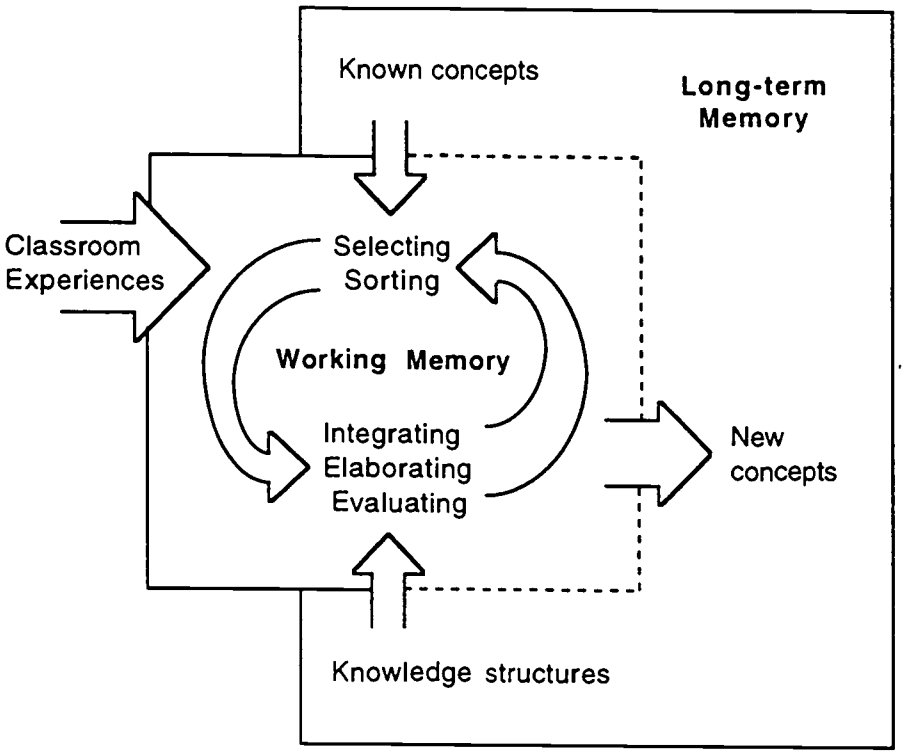

Figure 1. Diagram of the way curriculum relevant classroom experiences are processed in working memory.

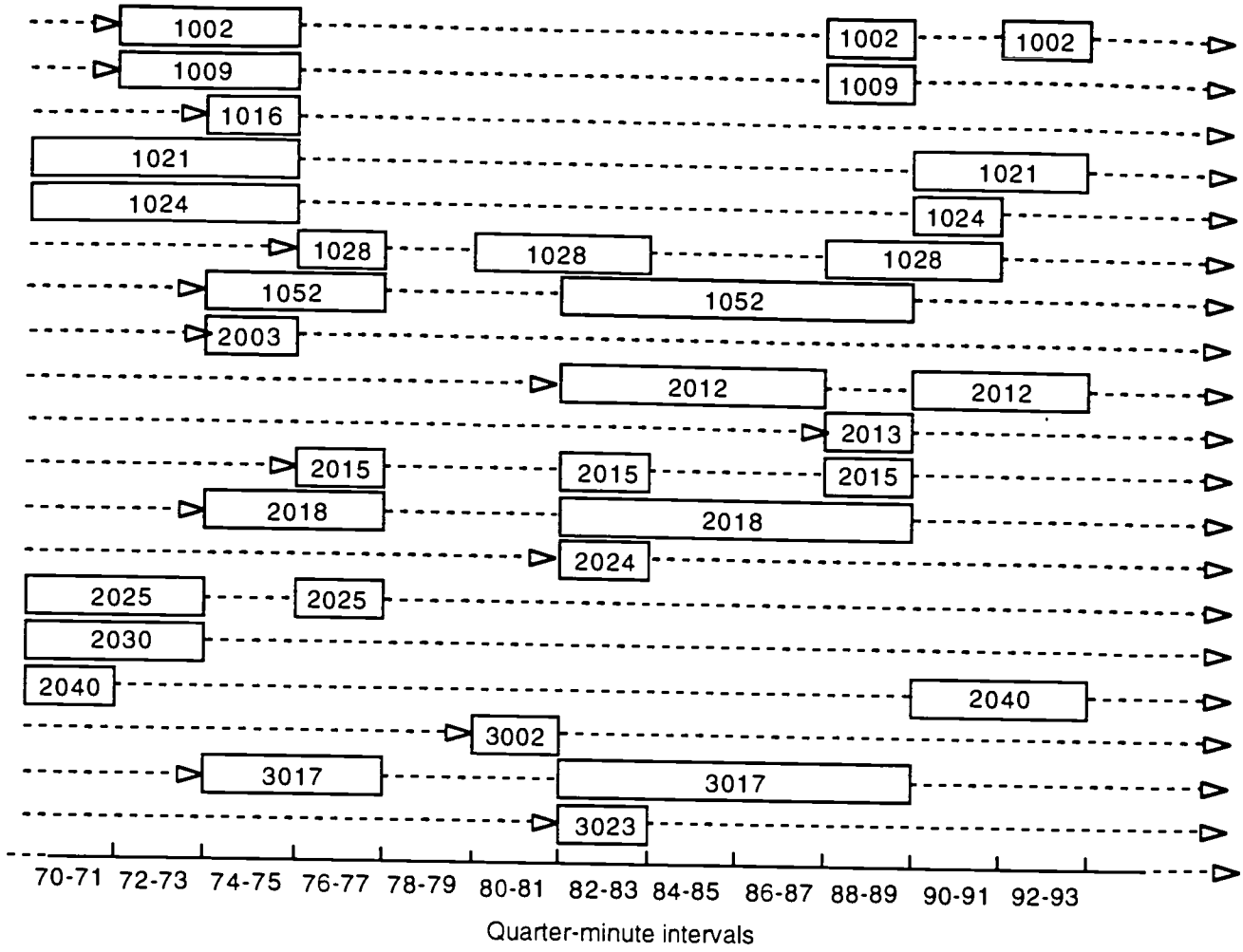

Figure 2. The dispersion of test-item content during the talk given by a visiting speaker, Day 6, Study 6.

Figure 3. The picture of a medieval town that Kim studied and colored for homework.

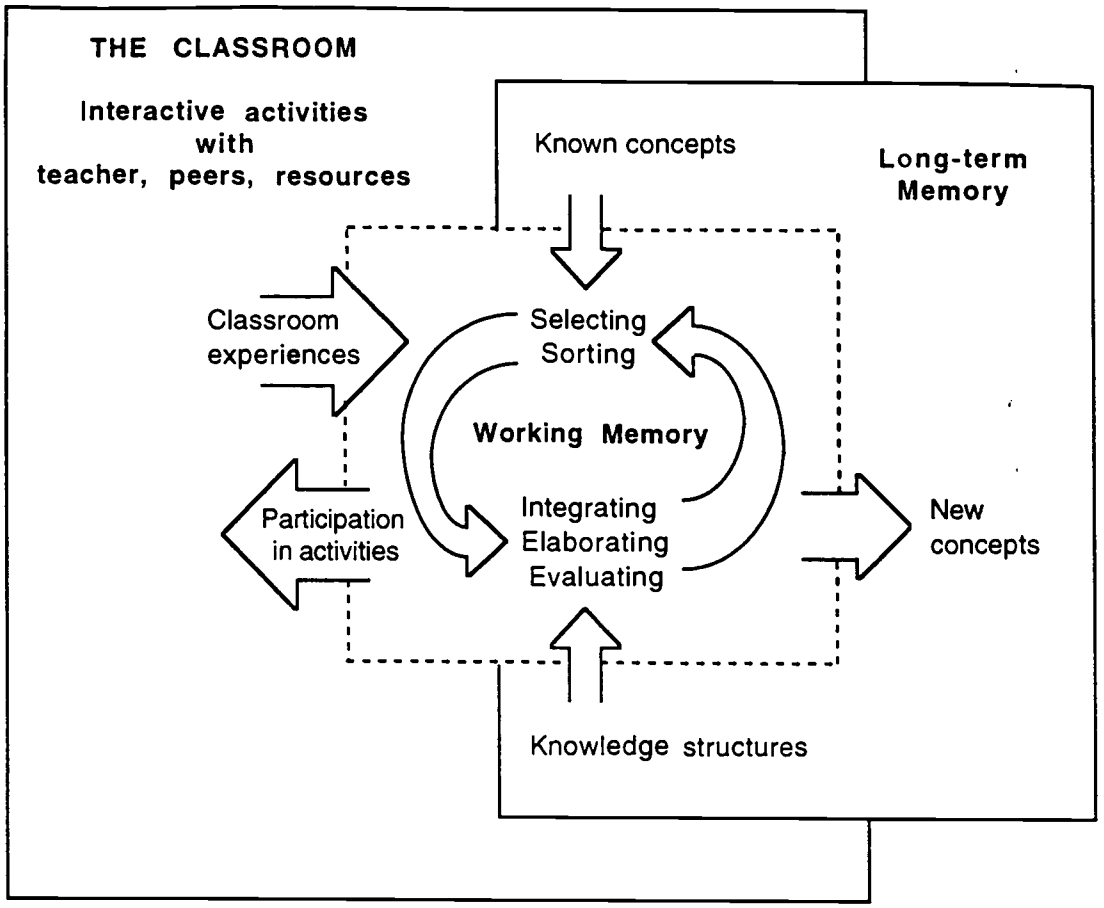

Figure 4. Diagram of the way curriculum relevant classroom experiences are processed in working memory, expanded to incorporate the classroom as part of the working space.

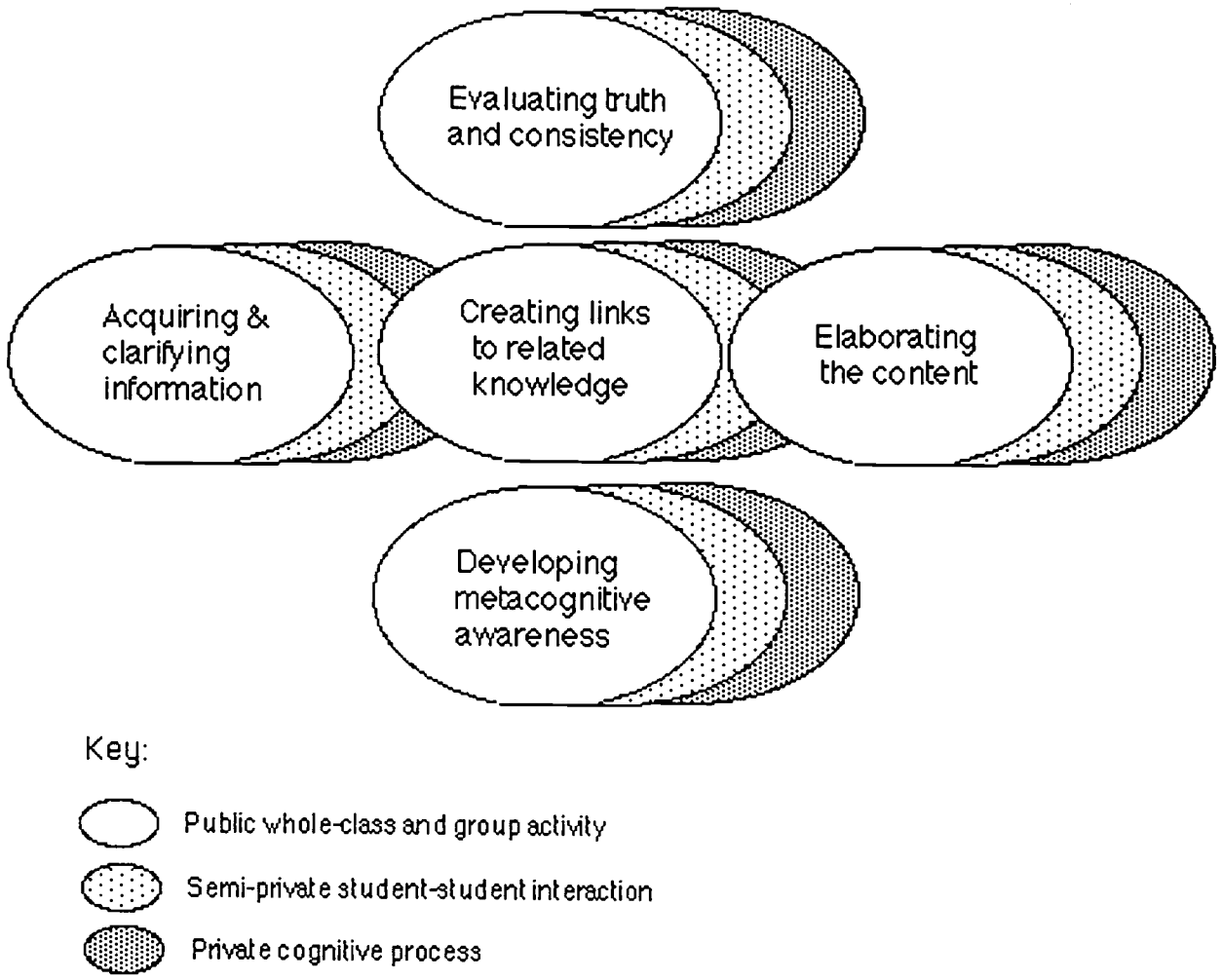

Figure 5. Knowledge acquisition processes/activities in the three interactive layers of student experience.

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