Periodical volume

Unterrichtswissenschaft $lt;Weinhei> - 29

Achtenhagen [u.a.], Frank

in: Periodical

391 page(s)

Nutzungsbedingungen

DigiZeitschriften e.V. gewährt ein nicht exklusives, nicht übertragbares, persönliches und beschränktes Recht auf Nutzung dieses Dokuments. Dieses Dokument ist ausschließlich für den persönlichen, nicht kommerziellen Gebrauch bestimmt. Das Copyright bleibt bei den Herausgebern oder sonstigen Rechteinhabern. Als Nutzer sind Sie sind nicht dazu berechtigt, eine Lizenz zu übertragen, zu transferieren oder an Dritte weiter zu geben.
Die Nutzung stellt keine Übertragung des Eigentumsrechts an diesem Dokument dar und gilt vorbehaltlich der folgenden Einschränkungen:
Sie müssen auf sämtlichen Kopien dieses Dokuments alle Urheberrechtshinweise und sonstigen Hinweise auf gesetzlichen Schutz beibehalten; und Sie dürfen dieses Dokument nicht in irgend einer Weise abändern, noch dürfen Sie dieses Dokument für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, aufführen, vertreiben oder anderweitig nutzen; es sei denn, es liegt Ihnen eine schriftliche Genehmigung von DigiZeitschriften e.V. und vom Herausgeber oder sonstigen Rechteinhaber vor.
Mit dem Gebrauch von DigiZeitschriften e.V. und der Verwendung dieses Dokuments erkennen Sie die Nutzungsbedingungen an.

Terms of use

DigiZeitschriften e.V. grants the non-exclusive, non-transferable, personal and restricted right of using this document. This document is intended for the personal, non-commercial use. The copyright belongs to the publisher or to other copyright holders. You do not have the right to transfer a licence or to give it to a third party.
Use does not represent a transfer of the copyright of this document, and the following restrictions apply:
You must abide by all notices of copyright or other legal protection for all copies taken from this document; and You may not change this document in any way, nor may you duplicate, exhibit, display, distribute or use this document for public or commercial reasons unless you have the written permission of DigiZeitschriften e.V. and the publisher or other copyright holders.
By using DigiZeitschriften e.V. and this document you agree to the conditions of use.

Kontakt / Contact

DigiZeitschriften e.V.
Papendiek 14
37073 Goettingen
Email: info@digizeitschriften.de

Graham Nuthall

Understanding how Classroom Experience Shapes Students' Minds

Zum Einfluss von Unterrichtserfahrungen auf das Schülerverhalten

This article is concerned with two related questions: How do the actions of teachers shape students' experiences? What do students learn from their classroom experiences? Drawing on data from six studies of individual students' experiences and learning in science and social studies units, three characteristics of student learning are identified: (1) what students learn from the same classroom activities is relatively unique, (2) learning is determined by experience not ability, (3) what students learn is dependent on student-created, not teacher-managed activities. In order to illustrate how classroom activities shape student learning experiences, the experiences of three students are analysed as they participate in a typical science activity. Their unique experiences are determined by their simultaneous participation in three socio-cultural systems: (1) the teacher managed instruction-evaluation system, (2) the peer interaction and relationship system, (3) the student's internal cognitive and emotional system. The interaction of these three systems determines how students learn and how their minds are shaped by the structures embedded in their classroom experiences.

Der Artikel ist zwei aufeinander bezogenen Fragen gewidmet: Wie beeinflussen Lehreraktionen die Schülererfahrungen? Was lernen die Schüler von den Erfahrungen, die sie im Unterricht machen? - Auf der Grundlage von sechs Studien zu Erfahrungen, die Schüler machen, und zu ihren Lernprozessen im naturwissenschaftlichen bzw. im sozialkundlichen Unterricht werden drei Charakteristika des Lernens von Schülern herausgearbeitet: (1) Schüler lernen vor dem Hintergrund desselben Unterrichtsgeschehens individuell höchst unterschiedlich; (2) Lernen ist überwiegend durch die gemachten Erfahrungen und nicht durch die eigenen Fähigkeiten determiniert; (3) das Lernen von Schülern beruht überwiegend auf schülerbezogenen und nicht auf lehrerdominierten Aktivitäten. - Um näher zu zeigen, wie das Unterrichtsgeschehen die Lernerfahrungen der Schüler prägt, werden die Erfahrungen von drei Schülern im naturwissenschaftlichen Unterricht analysiert. Die je individuellen Erfahrungen sind zentral dadurch bestimmt, dass sie auf der simultanen Teilhabe an drei soziokulturellen Systemen beruhen: (1) dem vom Lehrer bestimmten Instruktions-Evaluations-System; (2) dem Peer-Interaktions-und -Beziehungs-System; (3) dem schülerinternen kognitiven und emotionalen System. Die Interaktion zwischen diesen drei Systemen bestimmt, wie Schüler lernen und wie sie von den Strukturen beeinflusst werden, die sich über ihre Unterrichtserfahrungen herausbilden.

1. Introduction

This article is about two inter-related questions: How do the actions of teachers shape student experiences in the classroom? and What is it that students learn from their classroom experiences? Together these two questions define what we need to know in order to understand and improve the quality of student learning in school.

Teaching involves two kinds of processes: the planning and setting up of learning activities that are intended to engage the minds of students in ways that produce learning, and the management of student engagement in those activities. Management of student engagement requires teachers to be continuously involved in making moment by moment decisions in a constantly changing context.

... classrooms are complex social settings in which teachers must process a great deal of information rapidly, deal with several agendas simultaneously, and make quick decisions throughout the day. (Brophy & Good (1986, p. 370)

No matter how well learning activities are planned and set up, the way students engage in those activities is largely unpredictable. This means that a teacher is constantly involved in deciding whether to continue each activity or stop it; whether to give additional instructions or leave the students to manage or solve the problem for themselves; whether to respond to immediate student needs or to leave them until an activity is finished. In this sense, teaching is always a spontaneous and creative activity in which the teacher is responding to whatever signs are available that indicate how students minds are engaged by the activities that make up the intended curriculum (Clark & Peterson, 1986; McNair, 1978).

The problem with this continuous decision-making is that teachers do not have direct access to how the students' minds are interpreting and understanding classroom activities. No matter how sensitive and responsive a teacher is, she is always responding to secondary indicators of the learning process such as the look in students' faces, what they seem to be doing, how they are responding to the requirements of the activity (Jackson, 1968). Furthermore, in average size classrooms, the teacher can only sample these visible indicators from some children some of the time (Dahloff & Lundgren, 1970).

The consequence of this lack of direct and complete information about the learning process is the enshrinement of the busy active classroom as the model of effective teaching. Classroom management procedures are based on this model. Learning activities are designed with this model in mind. The performance assessment of teachers focuses on this model and teachers are rewarded when their classrooms reflect this model (McKay & Marland, 1978 March).

Increasingly also, research on teaching is based on this model. Many studies of effective teachers focus on trying to identify the behaviours that make up the busy active classroom (e.g., Ramsay & Oliver, 1995). Those who write from a sociocultural perspective have defined learning as the increasingly expert participation of students in a classroom of this kind. In order to avoid direct reference to the minds of students, they have idealised participation in classroom activities as both the process and end of learning (Rogoff, 1995; Rogoff, Matusov, & White, 1996).

There are, however, serious problems with the assumption that the enthusiastic engagement of students in classroom learning activities leads to effective curriculum learning. Frequently students already know or can do what the activities are designed to teach. The signs that teachers use to indicate how students' minds are engaged by an activity are culturally and often contextually specific. Indicators of interest and engagement, of knowing and understanding, vary with the cultural background of the students and the history of their experiences with teachers. Students learn to play the reciprocal game. They learn to display the indicators of interest and engagement when they are, in fact, bored or thinking of other things. They learn to manage their involvement in classroom activities in such a way that they carry out, with the least possible effort, only those behaviours and tasks that are likely to be noticed and evaluated. Occasionally, of course, they can get caught up in the fascination or excitement of a specific learning activity, but most of the time, with most teachers, their focus is on reducing both ambiguity and effort to a minimum (Doyle & Carter, 1984).

If the most important goal of education is the learning that shapes student's minds and not just the effective management of classroom activities, then we need a better understanding of the way this learning takes place. This applies not just to the immediately visible learning of appropriate behaviours or curriculum content but also to more significant changes that classroom experience produces in students' knowledge, beliefs, attitudes and abilities. If Vygotsky (1978, 1981) was right in claiming that the higher mental processes originate in culturally structured social activities, then we need to understand how the social interactions of the classroom structure students' experiences and translate into the development of their higher mental processes. The classroom has been viewed as a learning community in which students acquire expertise in managing their own learning (cf., Brown, 1994; Brown & Campione, 1994) but so far there is little research on how the communal experience of students in such a community translates into the shaping of students' minds.

The purpose of this article is to develop our understanding of how classroom experiences shape student minds and of how the actions of teachers shape student experiences. This will be done through an examination of how classroom activities are structured and how the actions of teachers in setting up and managing classroom activities interact with the students' peer relationships and personal knowledge and beliefs to shape the ways in which students experience and learn from those activities. It is intended to clarify our understanding of the complex relationships that exist between classroom teaching and student learning.

2. The research design and the data

The research studies that have produced the data used in this paper have departed from the traditional studies of teaching methods and teaching effectiveness by focusing on the process of learning rather than the process of teaching. We have deliberately moved away from research designed to tell teachers what to do towards research designed to tell teachers what goes on in the minds of students so that they will understand better the effects of the activities they design and the moment-by-moment instructional decisions they must make (Alton-Lee & Nuthall, 1990)

Table 1:
Characteristics of the studies and the individual students observed and interviewed

Topic of unit and hours of recorded time per student	Students (gender)	Age (years)	Achievement (percentile)[a]
Study 2. Social Studies: The Middle Ages in England (52.4 hours over 21 days).	Amy (f)	9.9	93
	Kim (m)	9.8	30
	Sam (m)	9.6	14
Study 3. Social Studies: New York: A study of cultural differences (6.4 hours over 5 days).	Ann (f)	12.5	55
	Mia (f)	12.4	96
	Jon (m)	11.8	97
	Joe (m)	12.2	55
Study 4. Science: Weather: observation and forecasting. (7.1 hours over 8 days).	Rata (f)	10.4	68
	Pam (f)	10.4	21
	Jan (f)	10.4	70
	Tui (m)	10.4	11
Study 6. Science & Social Studies Antarctica: Conditions, people, animals, and plants. (13.4 hours over 6 days)	Paul (m)	12.2	89
	Jane (f)	11.5	83
	Joy (f)	11.10	70
	Jim (m)	11.9	56
	Teine (f)	11.4	34
Study 7. Social Studies: Ancient Egypt. (10.3 hours over 8 days)	Alice (f)	10.7	68
	Jerry (m)	9.10	73
	Kent (m)	10.0	25
	Verity (f)	9.5	28
Study 8. Social Studies: Ancient Egypt (13.2 hours over 8 days)	Amity (f)	10.5	32
	Dean (m)	10.0	35
	Julie (f)	9.9	68
	Kirk (m)	10.5	81
Study 9. Science: Light & color (7.4 hours over 8 days)	Austin (m)	10.9	85
	Karin (f)	10.11	64
	Shaun (m)	9.9	46
	Sonya (f)	11.1	26
Study 10. Science: Light & color (8.9 hours over 6 days)	Eleanor (f)	11.4	95
	Jordan (m)	10.3	55
	Seth (m)	11.2	36
	Sylvia (f)	9.8	41

[a] *Average age-related percentile on at least 3 school school-administered standardized achievement tests, including reading comprehension.*

The basis of our studies has been detailed tracking of the experiences of selected individual students during the course of curriculum units in science, social studies, and technology. This has been done by using sets of ceiling-mounted miniature video-cameras (focused on the whole class and on small groups of students), having each student wear miniature broadcast microphones, and having trained observers record individual students' behaviours and use of materials and resources. Students also recorded their own relevant out-of-class activities (including homework) each day. Learning was assessed using pre-and post-tests and extended interviews that explored student knowledge and thinking about the curriculum content and their feelings and beliefs about their learning experiences.

All of the recorded and observational data for each student, along with their test and interview responses, was broken up into 'concept-files'. A concept-file was created for each student for each concept, proposition, belief, or principle that that the teacher intended the students to learn during the unit or that the student might have learned from the available resources. Each concept-file contained all the data for every experience that a student had that was relevant in any way to the specific concept, proposition, belief, or principle, along with the student's recall and beliefs about those experiences. In each study there were between 58 and 267 concept-files per student. These concept-files allowed us to trace the cumulative sequence of experiences that each student had as they learned or did not learn each concept that made up the intended learning outcomes of the units.

Note that here and for the rest of this article the term "concept" will be used as a generic term to refer to any aspect of knowledge (proposition, concept, belief, understanding, generalisation, or principle) that is the intended learning outcome of a curriculum unit.

To date we have completed the fieldwork and most of the data analysis for eight studies in six different classrooms. Each study has involved the observation and recording of all the experiences of 3-6 students selected to represent differences in gender, ethnic background and academic ability. In each classroom the teachers used a mixture of whole-class, small group, and individual activities. Details of these eight studies, and the selected students in each study are reported in Table 1.

3. Creating a model of student learning

Our analysis of the concept-files for each student in each study has led us to identify the kinds of experiences that students need in order to learn curriculum content from their involvement in classroom activities. On this basis we have developed a procedure for identifying the number, timing, content, and sequence of relevant learning experiences that has allowed us to predict, with about 80 - 85% success, whether a student will (or will not) learn and remember a specific concept (Nuthall, 1999b).

In general our findings show that the learning of curriculum content is the result of the accumulated effect of a critical number of relevant learning experiences. It seems likely that a representation of each learning experience is stored in a long-term working memory for a period of about two days. It disappears from this working memory unless it is joined by representations of the content of further relevant experiences within the two-day period.

Evidence from the way students recall their classroom experiences suggests that while it is stored in working memory each experience is interpreted, elaborated, and evaluated through connections that are made with concepts already stored in long-term memory and with representations of further new experiences. In a typical classroom context, when an experience contains all the information a student needs in order to understand a concept, it takes 3-4 such experiences for the processes of interpreting, elaborating, and evaluating to create the new concept. Once stored and available in long-term memory, the new concept takes on a life of its own and plays a role in the interpretation and understanding of further new experiences. When the information contained in a relevant experience is incomplete, partial, fragmented or contradictory, additional specific types of experiences are required. The details of what is involved in analysing the content and relevance of specific experiences in relation to different learning outcomes have been reported in Nuthall (1999b) and Nuthall & Alton-Lee (1993).

4. The nature of student learning in the classroom

Analysis (using the concept-files) of the learning experiences of individual students has alerted us to three significant characteristics of the learning process that form part of the bridge between classroom activities and student learning outcomes. These are: the relative uniqueness of individual student learning, the lack of connection between the learning process and student ability, and the primary significance of student-generated learning activities and experiences.

4.1 The relative uniqueness of individual student learning.

Our data indicate that in typical science and social studies units, what most students learn is unique to themselves or to a few other students. Table 2

Table 2: The percent of concepts that were already known and learned by different numbers of students (for the four selected students in each of four studies)

Number of students sharing the same prior knowledge or learning outcome	Social studies units		Science units	
	Study 7	Study 8	Study 9	Study 10
1. The percent of concepts that were already known by:				
all 4 students	10.5	6.8	25.0	27.3
3 of the students	18.4	14.9	15.0	18.2
2 of the students	30.3	31.1	27.5	18.2
only 1 of the students	27.6	29.7	22.5	22.7
none of the students	13.2	17.6	10.0	13.6
Average percent of all concepts already known by each student:	46.4	40.9	55.6	55.7
2. The percent of concepts that were learned during the unit by:				
all 4 students	1.3	1.4	0	4.5
3 of the students	6.6	10.8	2.5	6.8
2 of the students	31.6	28.4	22.5	20.5
only 1 of the students	32.9	28.4	30.0	27.3
none of the students	27.6	31.1	45.0	40.9
Average percent of all concepts that were learned by all students:	30.3	33.0	20.6	26.7

shows the degree of uniqueness of the learning of the four selected students in each of four different classrooms.

What this table shows is that, for example, in Study 7 (first column of the table) 10.7% of the concepts (propositions, principles, beliefs, etc.) assessed in the outcome test for that study were already known before the unit by all four of the selected students. A further 18.4% of the concepts were already known by three of the four students, but not by the fourth. A further 30.3% of the concepts were known by two of the students and not by the other two. Another 27.6% of the concepts were known by only one of the four students, and the remaining 13.2% of the concepts were not known by any of the four students. Similarly, only 1.3% of the concepts were learned by all four of the selected students. A further 6.6% of the concepts were learned by three of the four students, but not by the fourth. A further 31.6% were learned by two of the students and not by the other two. And so on.

To summarise, on average, about half (46.4%) of the concepts assessed in the outcome test were known before the unit by the four students. However, only 10.5% were known by all four students. On average the students learned about 30.3% of the concepts they did not know on the pre-test. But only 1.3% of those concepts were learned by all four of the students. This relative uniqueness of student learning was partly the result of the wide variation in background knowledge and partly the result of individual differences in the way students participated in classroom activities (see Table 4 below). The implication is that even though teachers may structure and organise classroom activities in ways designed to create the same learning experiences for students, students' learning is predominantly unique.

4.2 The lack connection between the learning process and student ability.

Perhaps the most significant, and unexpected, finding to emerge from our analysis of student learning was the lack of apparent relationship between the learning process and student ability. We found that student learning of curriculum content was dependent on the frequency, content, and timing, of student experiences, and not related to the student's level of academic aptitude or ability.

This contradicts the common assumption that students with high academic aptitude generally learn more easily or efficiently. They are thought to grasp ideas more quickly and require less explanation or less practice. Low ability students are said to be "slow learners" and to have a "lower capacity to acquire knowledge" (Snyderman & Rothman, 1987).

Table 3 reports the results of predicting which concepts each student would and would not learn on the basis of the content, frequency and timing of their classroom experiences. The results are from the studies (2, 3, 4, and 6) in which we have completed this analysis.

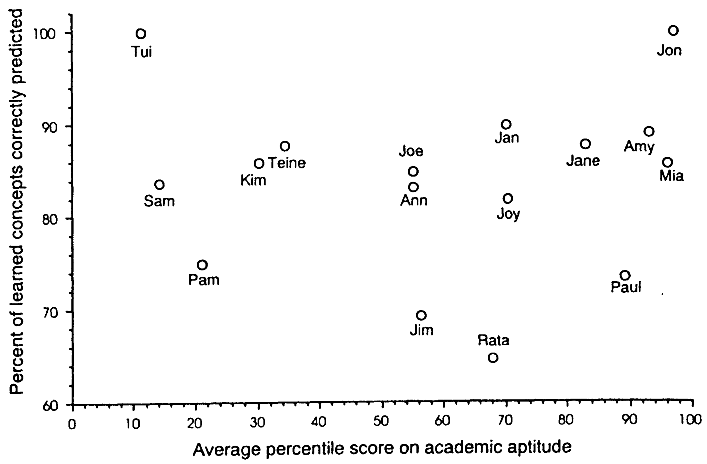
It is clear from this table, that there is no relationship between (a) the level of success in predicting what concepts students would learn and not learn based

Table 3: Prediction success for concepts learned and not learned in Studies 2, 3, 4, and 6 using prediction procedures detailed in Nuthall & Alton-Lee (1993)

	Number of concepts learned	Percent predicted learned	Number of concepts not learned	Percent predicted not learned	Aptitude (average percentile)
Study 2					
Sam	37	84	39	85	14
Amy	55	89	17	82	93
Kim	43	86	27	85	30
Study 3					
Ann	20	85	20	70	55
Mia	28	86	15	87	96
Jon	12	100	5	80	97
Joe	18	83	13	77	55
Study 4					
Jan	10	90	12	83	70
Pam	16	75	27	85	21
Rata	17	65	20	80	68
Tui	14	100	33	70	11
Study 6					
Jane	65	88	52	85	83
Joy	61	82	55	78	70
Jim	62	69	53	91	56
Paul	72	74	31	74	89
Teine	41	88	89	80	34
Totals	571	83.4	508	81.1	

on their classroom experiences, and (b) the academic aptitude of the students as measured by school-administered nationally standardised tests.1 Figure 1 shows this relationship for the concepts that the students did learn.

Figure 1:
The relation between predicting what students learn and their academic aptitude.

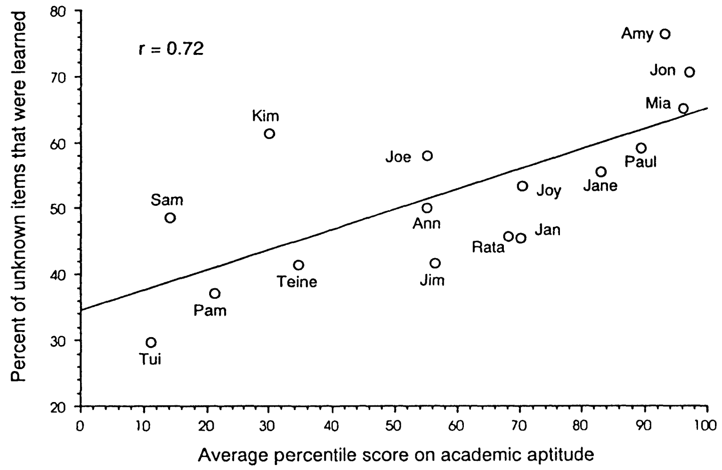


If students with higher ability learned more efficiently or more quickly, our prediction procedures should have under-estimated what the higher ability students learned, and over-estimated what the lower ability students learned. This would produce a curvilinear relationship between prediction success and academic aptitude, with the highest level of prediction success for students with middle levels of academic aptitude. There is no evidence of such a curvilinear relationship in Figure 1.

The results were the same for concepts that were not learned. Our prediction procedures should have over-estimated the number of concepts the high ability students did not learn and under-estimated the number of concepts the low ability students did not learn. There was no discernible relationship between level of academic aptitude and success in predicting what students would not learn (see Nuthall 1999a for more detailed data).

It might be argued that with a relatively small number of students such relationships would not be apparent. But the same data show other relationships that do fit standard assumptions. For example, there was a very clear relationship between academic aptitude and the number of concepts learned (r = 0.72, see Figure 2)

Figure 2: The relationship between the percent of unknown concepts that were learned and academic aptitude



These data show that while the amount that students learn is related to their background knowledge and academic aptitude, there is no causal connection between academic aptitude and what they learn. What students learn is predictable from their classroom experiences regardless of their ability or background knowledge.

It seems likely that measures of academic aptitude reflect what students have learned, rather than the cause of what they learn. Students with higher levels of aptitude access or create more learning opportunities than students with lower levels of aptitude. The difference does not lie in how their minds process experience but in how they make use of, or create, the opportunities to participate in a wider range of learning activities.

4.3 The significance of self-generated learning experiences.

The data from Study 6 was examined in detail to identify how the learning experiences of the more and less able students differed. All of the experiences in each concept-file for each student were analyzed and classified into those that occurred during teacher designed and managed activities and those that occurred during self-selected or self-created activities.

The teacher-created and managed activities were (a) those activities in which the teacher was directly involved (e.g. whole-class or small group discussion, one-to-one talk with the teacher, video presentations, teacher-read story) or (b) those individual activities designed and set by the teacher that students were required to do (e.g., a writing activity, required reading). The self-selected and self-generated learning activities were classified into three different categories.

a. *Choice of teacher designed activities.* These consisted of activities that were designed by the teacher so that the student could choose among alternatives (e.g., a student could choose one of a set of readings, games or other resources provided by the teacher, or a student could choose one of a set of topics to investigate or write about).

b. *Self-designed activities and use of resources.* These consisted of those activities that the students designed or created for themselves (e.g. the student added a section or drawing to a report, selected their own topic to research or write about, did additional research or homework). For example, during Study 6, the teacher introduced the students to a card game that was designed to illustrate the food chain in Antarctica. Some of the students developed their own version of the game and played it during the lunch hour.

c. *Spontaneous peer talk.* These consisted of occasions when students talked with each other about relevant content. These spontaneous conversations (discussions, arguments, word-plays) occurred during individual, group, or whole-class activities.

Many concept-files contained more relevant learning experiences than the minimum needed to learn the concept. Where there were enough learning experiences during teacher-managed activities for learning to occur, the concept was counted as being learned during teacher-managed activities. Where there were not enough experiences during teacher-managed activities for the concept to be learned, and additional learning experience(s) came from self-selected or self-generated activities, these were classified as learning that required a self-generated learning experience. The results of classifying all the concept-files for the selected students in Study 6 are reported in Table 4.

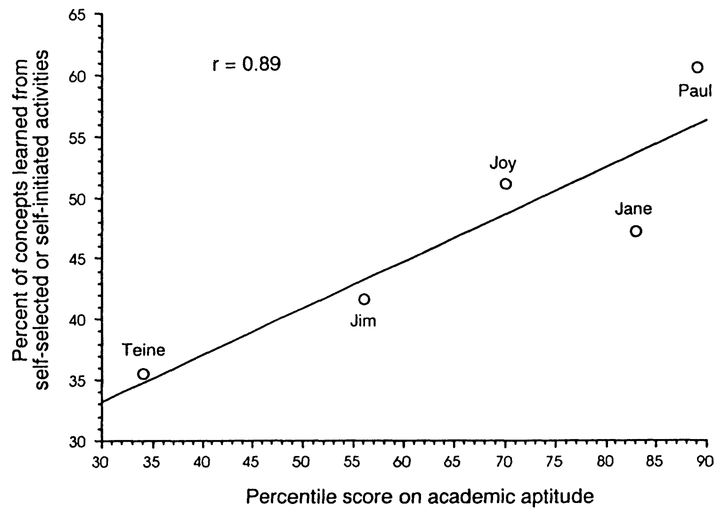
Across all students, only about 50% of the concepts that they learned were dependent on experiences occurring during teacher-managed activities. About

Table 4:
Percent of learned concepts where a critical learning experience was teacher-managed, self-selected, or self-created (data from Study 6)

	Aptitude percentile	Teacher managed activities	Choice of teacher-designed activities	Self-designed activities & use of resources	Spontaneous peer talk
Paul	89	39.3	32.8	13.1	14.8
Jane	83	52.7	25.5	10.9	10.9
Joy	70	48.9	26.7	8.9	15.6
Jim	56	58.3	6.3	8.3	27.1
Teine	34	64.5	22.6	6.5	6.5
Average percent		51.3	23.3	10.0	15.4
Total number of learned concepts		123	56	37	24

quarter were dependent on experiences that occurred during activities that the students created for themselves. The student with the highest academic aptitude score (Paul) was the least dependent on teacher-managed activities and the student with the lowest academic aptitude score (Teine) was the least likely to learn from self-generated activities. The strength of the relationship between self-selected and self-generated learning activities and academic aptitude is depicted in Figure 3.

Figure 3: The relationship between academic aptitude and the percentage of concepts that were learned from self-selected or self-initiated activities.



These data suggest that the differences in what students learn in the same classrooms are created by differences in the activities that they select and the activities that they generate for themselves. This, in turn, suggests that differences in motivation and interest may be the primary cause of differences in what students learn. Those students who are most interested in the topic, or most strongly motivated to find out more about it, are the ones who learn most regardless of differences in academic aptitude. Thus scores on academic aptitude tests may be related to student learning through differences in student motivations and interests, not intellectual capacity.

This explanation does not, however, take into account what we know about the role of background knowledge (cf. Dochy, Segers, & Buehl, 1999; Tobias, 1994). Students who learn more, for whatever reason, must progressively accumulate a larger knowledge base. Our studies of how students recall their classroom experiences and learning (Nuthall, 2000a, 2000b) show that prior knowledge plays a critical role in how students access and use what they have learned. As students accumulate more and more knowledge, they increase their ability to interpret, evaluate and integrate new experiences (cf. Bransford, Sherwood, Vye, & Reisser, 1986).

There is evidence that schooling does affect the development of cognitive skills such as memory (Cole, 1996; Nelson, 1996; Morrison, Smith, & Dow-Ehrensberger, 1995; Sharp, Cole, &Lave, 1979). There is also evidence that scores on academic aptitude tests are strongly affected by school experiences and that the apparently normal distribution of such scores is an artifact of the normal distribution of the ages of children within single grade levels (Cahan & Cohen 1989; McDonald, 1998). In addition, the theoretical work of Vygotsky (1978, 1981) and Leont'ev (1981), and the experimental work of Gal'perin (Haenen, 1996) are based on the premise that the higher mental processes (including learning and thinking processes) are acquired through the internalisation of social activities such as the learning activities of the classroom.

The most probable conclusion seems to be that there is a reciprocal or circular relationship between classroom experiences and cognitive processes. The products of this circular relationship are the skills and motivations that determine effective participation in classroom activities and create within the student's mind an increasingly complex and well-structured body of knowledge and understanding.

Embedded in this circular relationship is the process of internalisation. According to Piaget (1962, 1978) internalisation involves the development of an internal or cognitive model of those structures and processes that a child encounters in the physical and social world. The patterning of experience that a child must manage and remember if she/he is to succeed in an activity comes to be represented in the mind in such a way that the child is able to replicate and use this patterning internally without reference to the external world. In other words, the child acquires the ability to interact with the world in her/his mind independently of, and in anticipation of, external events.

If classroom experiences shape the minds of students in some significant way, then it must be the consequence of the students' increasing expertise in managing their engagement in classroom activities. As they become increasingly expert in these activities, the structures and procedures that make up the activities become the structures and procedures that constitute their ways of thinking and learning.

The remainder of this article is concerned with identifying the structures and processes that are embedded in classroom activities and that seem the most probable candidates for becoming, through internalisation, the structures and processes of student minds. In doing this, it will be necessary to examine what determines how students participate in classroom activities and what are the relative roles of the teacher and students in shaping students' classroom experiences. The first part contains an analysis of the structures and processes that characterise classroom activities. The second part contains an illustration of how these structures and processes determined student experiences in a specific science activity in a Year 5/6 classroom.

5. The structure and process of classroom activities.

The term structure is widely used in discussions of classroom activities, and there are at least two different kinds of structure that can be distinguished. The first is the knowledge structure, or structures, characteristic of a particular curriculum area. The term 'genre' has been used to describe the distinctive patterns of language use, the logic, and the procedures, that distinguish one area of knowledge and investigation from another (cf. Berkenkotter & Hukin, 1995; Christie, 1989; Martin, 1992; Russell, 1996).

The second is the structure, or structures that are characteristic of the patterning or sequential organisation of classroom behaviour. The concept that seems most useful as a the basis for a generic analysis of the patterning of students' classroom experience is the concept of 'activity', as this has been defined by Wells (1999) based on the work of Leont'ev (1981) and Wertsch and his colleagues (e.g., Wertsch, Minick, & Arns, 1984). According to Wells, an activity is a "relatively self-contained, goal-oriented unit of activity, such as carrying out an experiment or writing a story" (Wells, 1999, p. 172). As such it consists of a sequence of behaviours or tasks that follow an expected pattern intended to achieve a goal. What holds it together are the mutually inter-related expectations of the participants about how it will be carried out. It is a repetitive pattern of tasks (with the goals, beliefs, roles, status and behaviour that go with the tasks) although the way the pattern is carried out will vary from occasion to occasion and context to context. It is, in other words, a familiar and expected way of achieving a particular type of goal (Van Oers, 1998).

The value of the concept of an activity is that it incorporates the psychological, social and cultural aspects of a mutually understood pattern of behaviour. It is similar to, but much broader than the concept of a 'schema' that has been used in research on cognition (cf. Brewer & Nakamura, 1984; Derry, 1996).

An activity has both structure and process. The *structure* describes what is common to the sequence of behaviours that occur on different occasions and in different contexts. However, what happens on any one occasion is not an exact replica of what happened on previous occasions. There are variations, and these variations are not just incidental or accidental. The *process* of carrying out an activity on a particular occasion is the product of the interactions between the individuals involved: their personal characteristics, goals, and past histories. The enactment of an activity involves both the structure (the expected and predictable sequences of tasks and behaviours) and the process (the dynamics of interactions between the individuals and their personal characteristics).

6. The tasks that make up a typical classroom activity

For the purposes of this analysis, a classroom activity is defined as a sub-unit within a larger curriculum unit or topic that is focused on a significant concept, understanding, principle or skill that the teacher intends the students to learn or acquire. Often such a sub-unit will revolve around a particular pattern of classroom organisation such as a whole-class discussion, a small group interaction, or individual seat-work. However, most of the sub-units defined as classroom activities involve some mixture of these patterns. So, for example, a social studies activity might begin with a brief whole-class discussion, change to a small group research activity, and end with the students working individually on a written report. What holds the activity together is the intended curriculum purpose or learning outcome.

In this paper the focus is on typical science activities in which the central element is a small group of students working together to carry out some kind of investigation or experiment. These kinds of activities appear to be increasingly common and much is claimed for them about students constructing their own knowledge and managing their own learning (cf, O'Connor & Michaels, 1996). In the data from our studies, typical science and social studies units consisted of four distinct but frequently overlapping components: instructions, carrying out the activity, writing or presenting a report, discussing the results. The first two were essential components, the last two were typical but not essential and depended on the pedagogical purpose of the activity. The first three always occurred in that order, although they usually overlapped with each other. The last component could be dispersed among the previous two. The following is a brief description of the kinds of tasks that made up each of these components.

a. *Instructions.* The teacher provides a set of instructions about what the students were expected to do. These could be spoken by the teacher, discussed with the students, printed on an instruction or worksheet, or some combination of these. The instructions were never fully explicit. Their meaning depended on the mutual understandings that the teacher and students had developed about what was expected in similar activities.

b. *Carrying out the activity.* The students engaged in an activity on the basis of their understanding of the instructions, their knowledge of what was usually expected in such activities, and their awareness of the consequences of following or not following the instructions and conforming to the implied expectations. In addition, their behaviour was constrained by the availability and usefulness of the resources and their ability to negotiate and manage the social context in which the activity was carried out.

c. *Preparing a report.* Almost always teachers required students to record or report on the outcomes of the activity. Whatever the activity, it was rare for students not to be required to show or record something that was evidence of what they had done. Since this was the aspect of the activity that was most likely to be evaluated, it exerted a controlling influence on the way the activity was carried out. Often it was the only aspect of the content of the activity that the teacher actually saw and was the only evidence the teacher had that the activity had been appropriately carried out.

d. *Discussing the results.* During, or at the end of the activity, the teacher usually discussed the activity or its outcomes with the students. These discussions related to the components of the activity, the activity as a whole, or the outcomes of the activity. The purpose of these discussions was usually to provide the students with an account of what the activity and its outcomes was intended to mean or achieve. It was the occasion when the teacher related the physical aspects of carrying out the activity to the intended academic purposes and processes. Connections were made to previous activities, to previous knowledge, and to the implications implicit in the outcomes. Even if the students had no idea why they had carried out the activity, had interpreted its purposes quite differently from the teacher, had not completed the activity, or obtained the wrong outcomes, this discussion served to tell the students what they should have done, how they should have understood it, and what they should have concluded (cf., Wells, 1999).

7. The process of enacting classroom activities

On the surface it appears that the way students engage in classroom activities is a function of the teacher's instructions (the task design) and management of student behaviour. Much of the research on this type of classroom activity is based on this assumption. However, understanding this type of activity from the point Of view of student experience requires understanding how students are simultaneously involved in three different contexts or contextual systems, only one of which is under teacher control. Theses three sociocultural contexts or systems are: (1) the public system of classroom activities that the teacher designs, organises and manages both directly in face-to-face interaction with the students, and indirectly through individual and group tasks , (2) the semi-private system of peer interactions and relationships within the peer culture that is partly visible but largely invisible to the teacher, and (3) the private or internal system of the student's cognitive and emotional processes. Each of these systems has its own rules, procedures, and outcomes. While these sociocultural systems interact with each other, they are structured differently, involve different processes, and affect the learning process in different ways.

7.1 The instruction-evaluation system

This is the system of activities that the teacher designs and implements in the classroom. Typical classroom activities are largely ritualised with both teacher and students sharing a mutual understanding of the broad patterns of behaviour that are expected of them (Stigler & Hiebert, 1999). Some, such as whole class discussions, are directly under teacher control. Others, such as small group activities, are only under indirect control. In these activities, control is exercised through instructions and the ways students have learned to interpret these instructions. Although teachers may give explicit instructions, these must be interpreted by the students in relation to their past experience in that classroom. They must interpret what the teacher really intends them to do and what are the consequences of interpreting instructions and behaving in different ways. This interpretation process continues throughout an activity and usually involves continuing negotiation between the students and the teacher. As an activity progresses, new and unexpected circumstances occur and instructions must be reinterpreted in relation to them and to the exigencies of the social context, the physical resources, and the personal skills and knowledge the students bring to bear on the task. The behaviour structures and discourse that characterise this domain have been extensively analysed by researchers such as Bellack, Kliebard, Hyman, & Smith (1966), Wells (1994), and the Santa Barbara Discourse Group (Green, & Dixon, 1993).

7.2 The social interaction system

Classroom activities also take place within an established and on-going system of social relations between students. This system is made up of the informal patterns of roles, status, friendship groupings and changing personal relationships that constitute the social life of the students. It is held together by the peer culture - the fashions and norms that structure the way students see and are seen by each other. Doing things with others, even doing things in the presence of others, requires that the interests, needs, expectations, and approval of others be taken into account. A student is always aware that other students may have different understandings of the nature of the classroom task requirements, a different sense of how to carry out a classroom activity, different goals and interests. Students must balance or integrate the social interactions needed to carry out a classroom activity with the maintenance of their on-going social life and status inside and outside the classroom.

In the following excerpt from Study 6, Teine and her friends sustained a discussion about their boyfriends during a formal class activity. The teacher had asked the class to write down questions that they would like answered about Antarctica. A whispered conversation (often too quiet to be picked up by their individual microphones) developed between Teine and her neighbours.

Leigh:	(inaudible) if you want to get a boyfriend, get (inaudible).
Teine:	Yeah, but it's not for me, I just .. 'cause Nell said, oh, don't worry. But Nell wasn't planning. Nell said she was, Nell said she was trying to take John off you to give him to Maude.
Leigh:	Well, she's got no right to do that.
Teine:	Yeah, well (shrugs, throws sheet of paper onto Leigh's desk) Oh, no, I'll have to, I'll .. tell Nell I'll .. What?

Leigh (whispering, inaudible)

Teine: What do you mean (inaudible) no, well, all .. (starts singing to herself "Do you really want me baby") ...

Leigh (whispered, inaudible)

Teine: I know cause she's too shy. Everyone's teasing her about, she likes Colin, which is, I think is true. Colin.

Leigh (whispered, inaudible)

Teine: Nell, yeah, I know, but that's not true and now she's, she's really ...

At this point Teine picked up her pen and pretended to write as the teacher passed by. Once the teacher had passed she wrote a note and passed it to Abbie. This whispered conversation continued through the next class activity (watching a video) until it was replaced by the passing of notes. The observer recorded: "Teine receives note from Leigh, reads note. Teine writes on note and passes note to Abbie. Teine taps pen on desk, waiting for Abbie to read note, glances at Leigh and smiles. Teine tears up a piece of paper to use as a note and writes on it. She passes this note to Abbie via Leigh".

Although the evidence is fragmentary, our data, especially from the interviews, suggest that students are constantly aware of what other students think and feel about what they are doing. Analysis of student talk recorded on individual broadcast microphones shows that more than two thirds of student talk is with their peers compared with 14% with their teacher (Alton-Lee, Nuthall, & Patrick, 1993). Studies of how these social relationships shape student participation in teacher-managed activities have been carried out by, among others, Benenson, Apostoleris, & Parnass (1998), Jones (1985), Kollar, Anderson, & Palincsar (1994), Ladd (1999).

7.3 The student's own skill and knowledge system.

Completing an activity requires a student to apply her/his knowledge and skills to the available resources in ways that fit both the teacher's and peers' expectations of the activity. Each classroom activity is a personal journey starting with the student's prior curriculum knowledge, beliefs, and skills, progressing through each active encounter with the curriculum content, and ending with those changes in knowledge and belief that these encounters have created. It is usually only as the activity progresses that students find out exactly what knowledge or skill is required. Some parts of the activity will be difficult, other parts easy. Depending on their interest and past experiences with related content, students will often try to find ways to avoid difficulty and stay within a zone of comfort by re-interpreting the activity and re-negotiating responsibility for carrying out the requirements of the activity (cf., Doyle & Carter, 1984).

At the core of this system are the processes of interpreting, integrating and evaluating that take place in working memory as new experiences progressively change the nature of student knowledge and beliefs (Nuthall, 1999a).

The student's ability to manage this system depends on their metacognitive skills.

These three sociocultural systems interact continuously and are difficult to distinguish from each other. While they have been described here as distinct contexts or systems, they might also be described as different dimensions or aspects of the same activities. The teacher-managed instruction-evaluation system provides the general structure within which the other systems interact. It not only creates the instructional environment it also partly creates the social environment within which students participate in classroom activities. The social interaction system determines the roles and status that become part of each student's personal sense of self. There are those that argue that personality and sense of self are constructs of the social environment (cf., Gergen, & Davis, 1985). At the same time, the student's internal cognitive and emotional system is the integrating system for the other two systems. It is the student's internal cognitive and emotional system that determines how the student perceives, experiences and learns from an activity.

The following extract is from a whole-class discussion that took place during Study 6 (an integrated science and social studies unit on Antarctica). It illustrates the way the three contextual systems interact with each other during a whole class discussion under the teacher's control. The left hand column is the recording of the public discussion and the right-hand column are the recordings made through individually worn microphones of what the students were saying privately to each other ands to themselves. Only the recordings from the four selected students are included.

The teacher's intention was to talk about how humans also belong in a food chain, but the initial question ('what eats us') challenged and amused the students. Whenever a class discussion becomes very difficult, challenging, exciting or amusing to students it sets of a chain of audible private self-talk or private talk to immediate neighbours that teachers cannot hear. in this example, Joy understands the teacher has made a mistake and corrects the question to Jane. She then puzzles aloud about how to answer it. Jim treats the question as a joke and sustains the joke, partly to Ben and partly to himself. Paul, after agreeing privately with Masako, rehearses answers to the teacher's question to himself and to Robin beside him.

What these recordings of private self-talk and peer-talk reveal is that even when the activity is public and teacher-controlled, students are simultaneously participating in the social context of their immediate peers as well as the hidden context of their own thoughts.

To summarise the analysis to this point, a typical classroom activity involves the enactment of a structured sequence of tasks (instructions, carrying out the activity, preparing a report, discussing the results). How an individual student engages in that activity depends on the way the student is simultaneously involved in three contextual systems (instruction-evaluation, social interaction, personal knowledge and skill). At any one time the student must balance or integrate the expectations or requirements of each of these different systems. When students acquire expertise in classroom activities they inter-

Table 5:
Excerpt from a whole class discussion in Study 6.

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

nalise the structure of the activities and the rules and processes involved in participating in each of the three systems simultaneously. If Vygotsky and Piaget are right, it is both the structures of typical activities and the interactive processes that constitute the four systems that become the structures and processes of the student's mind. The work of Piaget focuses on the internalisation of activity structures and the physical context system (cf., Piaget, 1978). The work of Vygotsky and his followers (cf., Haenen, 1996; Vygotsky, 1978) focus on the internalisation of the sociocultural systems.

8. Carrying out a science activity in a Year 5/6 classroom.

In order to illustrate the structure and processes that make up a typical classroom activity, the behaviour of three students (Sonya, Shaun, and Austin) will be analysed as they engage in a science activity in a Year 5/6 classroom (see Table 1 for details of the students and the science unit). These three students (Sonya, Shaun, and Austin) were each working in different groups, so that while they are the focus of the analysis, their interactions with other students in their groups are also included.

The activity being examined was one of a set of three activities that were designed to go together. Each of the activities related to 'magnifying things' and was part of a science unit dealing with the properties of light. The intended purpose of the focus activity was to find out how objects are magnified when they are seen through water. The students were to place drops of water on a thin film of transparent plastic ("gladwrap") covering a printed page. They were to look through the drops and record whether the larger drops magnified the underlying print more or less than the smaller drips.

In the prior activity the students placed their thumb in a transparent glass jar and looked at it through the side of the jar. They recorded how much bigger their thumb looked when the jar contained water. In the subsequent activity, the students, measured the focal length of a magnifying glass by measuring how far away an object needed to be for the object to be seen in focus.

The "water-drop" activity had the typical activity structure described above (a sequence of instructions, carrying out the activity, writing a report, discussing results). The first and last parts of this sequence (instructions, discussing results) created the frame within which the other two parts were carried out. The teacher carried out the first and last parts as a whole class discussion. The second part (carrying out the activity) was carried out as a group task, and the third part (writing the report) was primarily an individual task with students in the same group discussing what they were writing.

8.1 Instructions

At the beginning of the three 'magnifying things' activities, the teacher gave the students a printed activity sheet that contained the following instructions: Place a piece of transparent plastic over a page of print in a book. Put a drop of water onto the plastic sheet. How do the letters look now? Find out what effect different sized drops of water have on the printing.

The instruction sheet also listed questions to focus the students' observations and thinking about the observations. The relevant questions were: What happens to light when it goes through water? Do large drops of water magnify printing more than small drops?

After the teacher handed out the instruction sheets she talked to the whole class about how they should get the required materials and write their report. During previous activities in this science unit, the teacher had given the students a set of three headings to organise their reports (What we did, what happened, what we observed). For the 'magnifying things' activities she did not provide this list but, in the class discussion, reminded the students of the headings.

Teacher: ... Stephen, what's the first thing you're going to write? Apart from the title which is 'Magnifying things'.

Stephen: What we did.

Teacher: Yeah, what we did, okay. What's the next thing you're going to write Karin?

Karin: What happened.

Teacher: Okay, and what's the final thing you're going to - oh the third thing you're going to write please Alice?

Alice: What we observed. ...

For this activity, the instructions consisted of three parts: the printed instructions which the students could keep and refer to during the activity, expectations based on previous related science activities that the teacher reminded the students about, and implicit expectations that were not referred to in the printed sheet or the class discussion. The students knew from their previous experiences in this class that they would be working in groups, that some of them had specific roles to play in their groups (e.g., responsible for resources), that the report should be written in a book they called their topic book, that the teacher would read and evaluate what they wrote in their topic book, that the teacher expected them to work together, focused on the task, without getting distracted, and so on. As the subsequent analysis will show, the teacher continued to amplify these instructions and make the implicit expectations explicit during her subsequent interactions with the student groups.

8.2 Discussing the results

Once the activity was completed (about 40 minutes after the instructions) the teacher had a final discussion with the whole class about what the students had done.

Teacher: Okay. Who can tell me ... And I made you all go and do this again. When you were making a hypothesis, you were guessing intelligently about which bubble, which drop would be ... would have the most magnifying effect. Who thought that the big drop was going to make it bigger? (Most of class raise their hands). I would have thought that to. Who found out that the big drop did make it bigger? (one student raises hand and then quickly puts it down again) Good, mmm. (laughs) . Okay, so you all discovered why. Who can tell me which drop magnified best? Nellie.

Nellie: The small drop.

The teacher then asked the students if they knew why the small drop magnified things more.

Teacher: Got any ideas why that was? Okay, why do you think it was, please, Bettina?

Bettina: 'Cause it was round.

Teacher: Right, okay. The small drop had a more rounded finish to it. When you put more water on it sort of went flatter didn't it? And what did we, what do we know about round things, round lenses. Karin?

Karin: They curve things.

Teacher: Yeah, we do know that, that's one thing we know. What else do we know about them?

Marcus: Makes things look bigger.

Teacher: Okay. Right, so that was the way it was magnifying, so that was excellent.

Taken together, the instruction sheet with the introductory discussion and this final discussion created a frame within which the "magnifying things". activities were carried out. The instruction discussion re-instated the requirements the students were familiar with from previous science activities, and added the specific requirements of this activity. The final discussion informed and/or reminded the students of what they had done and the underlying reasons that were the purpose of the activity.

9. How the students carried out the activity

Carrying out the activity began with designated members of each group collecting the materials they needed (magnifying glasses, a glass jar, and a piece of 'gladwrap') and returning to their group to negotiate who would carry out the different aspects of the experiments.

In order to get a general picture of how each group carried out the sequence of tasks that made up the 'water drop' activity, a category system was developed to classify the students' behaviours during the activity. Everything the students did was divided up into four major tasks (getting and clarifying specific instructions, interpreting instructions and getting resources, carrying out the procedures required by the instructions, and writing the report). Two further categories (social interaction unrelated to task procedures, spending time doing nothing active) were added to cover non-task related behaviours and just sitting.

Within these categories, the behaviours were further divided into those that were done individually, those that were done interactively with other students, and those that were done interactively with the teacher. The appendix lists these behaviour categories.

The percent of time the students spent engaged in these behaviours during the water-drop activity is reported in Table 6. This table is based on the time the students spent engaged in each of the behaviours because some of the behaviours (e.g, writing a report on what was observed) lasted for several minutes and others (e.g., using a resource in an alternative playful manner) lasted for only a few seconds.

Table 6:
The percentage of time students spend engaged in behaviors related to the four major components during the carrying out of a science activity (Study 9).

Type of behaviour	Sonya	Shaun	Austin	Average
A. Getting & clarifying instructions				
Teacher instructions to whole class	12.3	10.6	9.1	
Teacher instructions to group	3.2	2.4	1.2	
Student reading instructions	1.9	1.8	1.2	
Total	**17.5**	**14.7**	**11.5**	**14.5**
B. Interpreting instructions & getting resources				
Interactively with peers	4.5	8.2	3.0	
Interactively with teacher	2.6	0.6	2.4	
Individually getting resources	3.2	1.2	8.5	
Total	**10.4**	**10.0**	**8.5**	**9.6**
C. Carrying out required task procedures				
Carrying out procedures individually & interactively	6.5	4.1	5.5	
Talking with group about results & reasons	5.8	6.5	4.2	
Talking with teacher about procedures, results & reasons	12.3	10.0	14.5	
Carrying out incorrect procedure & accidents	2.6	1.8	1.8	
Engaged in alternative or playful activities	11.0	15.3	12.7	
Total	**38.3**	**37.6**	**38.8**	**38.2**
D. Social interaction unrelated to task procedures	2.6	1.8	0.7	**1.6**
E. Writing the report				
Organising materials & finding out what to do individually or interactively	4.5	10.0	4.2	
Talking about content of report with teacher	3.9	7.1	3.0	
Writing the report & illustrating it	13.0	10.6	26.7	
Reading own and other students' writing	1.9	5.3	6.7	
Total	**23.4**	**32.9**	**40.6**	**32.5**
F. Spending time gazing around, doing nothing	8.6	2.9	-	**3.5**
Total number of 15 second intervals	154	170	165	163

On average, the students spent about a quarter of the time (24.1%) on getting specific instructions, interpreting the instructions, and gathering the required resources. Nearly 40% of the time was spent carrying out the instructions and observing and discussing the results, and a third of the time (32.5%) was spent organising and writing the report.

The data in Table 6 was then re-organised according to whether the student was working individually, interactively with other students, or interactively with the teacher. The results of this analysis are reported in Table 7.

On average, the students spent about 30% of the time interacting with or listening to the teacher (talking to them in their group or to the class as a whole). They spent nearly the same amount of time interacting with, or listening to their peers. However, more than a quarter (28%) of the time spent interacting with peers was not related to the intended activities. About a third of the time the students were engaged in individual behaviours directly related to the in-

Table 7:
The percentage of time students spent working individually, interacting with peers, or interacting with the teacher during the carrying out of the activity (Study 9).

Social context	Sonya	Shaun	Austin	Average
Interacting with the teacher	31.8	28.2	29.1	29.7
Interacting with peers				
Related to intended activity	20.8	24.7	15.2	20.3
Unrelated to intended activity	7.8	10.6	4.9	7.8
Individual activity				
Related to intended activity	26.6	27.1	42.4	32.1
Unrelated to intended activity	13.6	9.4	8.5	10.4

tended activity (e.g., writing the report), and a further 10% of the time engaged in individual behaviours that were not directly related (e.g., using the magnifying glass to look at their own fingers). The high percentage of the time the students spent interacting with the teacher reflects the active role the teacher played monitoring and guiding how the students were working together in their groups.

9.1 Interpreting instructions and the sequence of major events.

The primary purpose of the activity was to compare the magnifying effect of different sized drops of water. Carrying out this task required the students to translate the instructions into the practical use of the resources, and to observe what they were supposed to observe. The sequence of each group's attempts to carry out the water drop experiment and the teacher's interventions are summarised in Table 8.

All three groups started the experiment on their own and, because of their difficulties, all three groups carried out the experiment a second and a third time initially with partial teacher help and finally with close teacher guidance. This pattern of moving backwards and forwards between successive tasks without completing them was characteristic of all the groups. Although the component tasks that make up an activity have a logical sequence, students do not experience them as self-contained entities that occur in that logical sequence. Completing each component task depends on the successful completion of each logically prior task. But the students' desire to complete the activity as quickly as possible meant that they constantly tried to move to the next task component before the previous one had been successfully completed. This was especially true of trying to write the report before they had completed their observations. As the subsequent analysis will show, it was a major concern of the teacher's to bring students back to completing prior tasks successfully. The actual sequence of events in each group is briefly described below.

Table 8:
The sequence of occasions the tree groups carried out the "drop" activity (Study 9).

Sonya's group	Shaun's group	Austin's group
1. Group attempts activity, teacher intervenes, they complete activity on their own Intervals* 23-45	1. Group attempts activity on their own Intervals* 29-35	1. Group attempts activity on their own Intervals* 32-42
	2. Teacher starts the group repeating activity, they complete it on their own Intervals* 36-41	
2. Teacher questions group and they repeat the activity again themselves Intervals* 95-111		2. Group attempts to do the activity again on their own Intervals* 99-103
3. Teacher questions group about results and does the activity with the group Intervals* 112-119	3. Teacher questions group about results and does the activity with the group Intervals* 98-109	3. Teacher questions group about results and does the activity with the group Intervals* 126-133

* *Note: The time intervals identified are 15 second intervals numbered in sequence from the time the students began carrying out the activity.*

The sequence of events in Sonya's group.

The experiment was started for the first time in Sonya's group by two of the girls with the help of a brief intervention by the teacher. Unfortunately Sonya distracted the group by accidentally putting her magnifying glass onto the drop of water. It was not until later when the teacher asked what they were doing that the group got back on task. This time the teacher told them directly how to put the drops of water on the sheet and advised them to look carefully through the drops of water.

Teacher: How about a bigger drop so you can see. I can see that one actually. Right, have a look at the word 'magnify', what happens when you get to the drop on 'magnify'?

Sonya (and others): It goes bigger.

Teacher: Okay so what's it actually doing to that drop of water?

Krista: It's magnifying.

Teacher: Oops, okay, right. What else do you have to do?

Krista: Um, place the piece of - um, find out what effect different size drops of water have...

Teacher: Right, so you need lots of little different size drops of water on there. (Teacher leaves group)

After one or two attempts to put more drops on their sheet, the group again became distracted. Alice tried to finish the task by telling the others what she thought the results should be, but they refused to agree with her.

Because the teacher had become aware that none of the groups were carrying out the experiment correctly she asked them to stop while she told the whole class to be careful with their results.

Teacher: If you're unsure what the big drips and the small drips do, have another look at that because it might be different than you thought it was going to be. Make sure you test the one with a small drop and a big drop. If you're not 100% sure on that one have another wee look at it because it might be different than you think.

Soon after this the teacher joined Sonya's group again and suggested they repeat the experiment. Sonya and Alice set up the experiment for the second time and, interrupted by a series of accidents, looked at the print on a gladwrap-covered page through different sized drops of water.

Sonya: Look there's the big one.

Alice: There's the small one. Small ones.

Sonya: Here's a small one. The small ones make the words go blurry ... there's a small one, it's gone blurry. That's a big one, it's made them go larger. Sonya accepted this as the result of the experiment and wrote in her report "the little drops made the words go blurry and the big drops made the words go ...". Later the teacher joined the group a third time and asked what they found out.

Teacher: Okay, what happened with the little drop?

Jake: It made it blurry.

Teacher: What happened with the big drop? Which - which magnified best?

Krista: The big one.

Sonya: The big drop.

Because they had reached the wrong conclusion, the teacher carried out the experiment with the group and insisted that they looked closely before deciding which drop magnified the most.

Teacher: Okay, which one is actually making it bigger? The little drop ... or the big drop

Sonya: The big one.

Alice: The big one.

Krista: The little one.

Jerry: They're both the same.

Teacher: Look very closely. Look very closely, Alice.

Alice: The little one.

Sonya: The little one.

Satisfied that they now had the right answer the teacher asked them to think about the reasons for their observations and went to work with another group.

The sequence of events in Shaun's group

In Shaun's group, Maurice organised the carrying out of the experiment and did most of the work himself. All except Maurice believed that the purpose of the task was to look at the drop of water through a magnifying glass. Maurice put a drop of water on the plastic sheet and described what he saw.

Maurice: See look it's making ... it's making the writing become a bit bigger.

Carly (looking through magnifying glass): And more clearer.

Shaun (looking through magnifying glass): And shiny.

Maurice then organised the group to put more drops on the page and, after they looked at the print through the drips, Maurice announced the result ("It is humungous! It makes the writing stand out").

At this point, the teacher joined the group and, although they told her they had done the experiment, she explained to them what they should be doing.

Teacher: ... have a look and see what happens when the drop's there.

Carly: It makes it clearer.

Teacher: Does it make any - is it just clearer or is it bigger?

Several say: Bigger.

The teacher suggested they put another, bigger, drop on the page and then left the group to complete the experiment on their own. They were still confused about the result. Patrick thought the drop "makes it smaller" and "colour-fuller". Carly thought the drop "just makes it normal". Maurice concluded "they're about the same".

It was at this point that the teacher told the whole class they should check their results carefully. This group did not respond, and it was not until the end of the time that the teacher joined Shaun's group again and asked them what they had found out.

Teacher: And what did you find?

Maurice: The big drops magnified more than the little drops.

Aware that they had also got the wrong result, the teacher carried out the experiment with the group telling them specifically what size drop and what size print they should be looking at.

Teacher: Put your big drop beside your little drop. So it's on the same size print. ...

Patrick: It still does the same.

Maurice: The little drop magnified it more.

Finally satisfied they had got the right result, the teacher also asked them to think about why, and moved on to the next group.

The sequence of events in Austin's group.

When Austin's group carried out the experiment for the first time, they were confused about what they were supposed to do. When they put the first drop of water on the plastic sheet they could not agree about what it did.

Austin: It doesn't look any different.

Rowena: It does so! Look. Its' magnifying. See look, it looks bigger.

Austin: I see.

Rowena: It makes things, um, bigger. It magnifies them. Austin stop playing with that. It magnifies it, that's an effect. An effect, yep, magnifies it.

Austin: Makes it bigger and blurry, big and blurry. Okay.

They were then distracted by an accident with the water and did not complete the experiment. Later after they heard the teacher tell the whole class to be careful checking their results, two of the girls in the group repeated the experiment while the others watched. They carried it out quickly, because they were already in the middle of writing their reports. They announced the results to the others.

Rowena: So the big one makes it look bigger than what the little drop does

Student: Eh?

Rowena: Makes it look bigger.

Austin wrote in his report "When we put the water on the wax paper it magnified the words".

Several minutes later the teacher joined the group and asked about their results.

Teacher: How are you going with the drips you people?

Austin: I've finished.

Rowena: We've finished.

Teacher: Okay, which drop was bigger, which drop magnified better, the small drop or the big drop?

As with the other groups, when she heard they had made a mistake, the teacher helped them carry out the experiment again, telling them exactly what to do. Once the two drops were on the plastic sheet, she asked them what they could see.

Teacher: Okay, there's your big drop, there's your little drop, compare the two. Which is bigger?

Paul: The big one makes it go small.

Teacher: Which one makes it go bigger, the big drop or the little drop?

Paul: The little.

Austin: The little one, cause it ...

As with the other groups, it was not until the teacher intervened and carried out the experiment with the students that they knew what they were supposed to do and what they were supposed to observe.

10. How the three systems work to determine what happens

The particular chain of events (outlined above) that occurred in each group were the result of the ways in which the students managed their participation in the three contextual systems. How the students participated in the different systems is analysed below.

10.1 The instruction evaluation system

Although each group had printed instructions to follow, these were not enough to guide their behaviour in the detail they needed to make the experiment work. The teacher moved from group to group monitoring the way the students were following the instructions and, initially, intervening briefly to correct or assist their activity. As she noticed that the students were having difficulty carrying out the experiment she spent more time with each group amplifying and scaffolding the procedures she intended them to follow.

Guiding the students' procedures. Most of the groups tried to develop a satisfactory procedure through trial and error, but because they were unsure of the purpose of the experiment, they had little idea what counted as being successful. Consequently, the teacher had to provide additional details. She helped them with the size of the drops of water ("That's a very small drop. Let's put another drop on"), the size of the print they should be looking at ("You're on a big word though, put it on the same size word. Might be easier to compare"), and the angle they should look through the drops ("You can't see sitting over there come over and have a look, have a look and see what happens"). She also needed to help them understand the focus of their observations ("is it just clearer or is it bigger?"). The problem the students had to deal with was how to work out what the teacher wanted them to see. The problem the teacher had to deal with was how to get the students to look at what she wanted them to see, without telling them exactly what they should be seeing.

It was only through constant interaction with each group that the teacher shaped the students' behaviour to match her model of the way a scientific experiment should be carried out. How she did this varied from group to group depending on her analysis of the difference between their behaviour and her model.

Clarifying misconceptions. While the teacher was assisting the students to carry out the experiment and observe the effects, she also assisted them to understand and explain the results. Part way through the activity, the teacher noticed that the students were making the common-sense assumption that big drops make things look bigger. She needed to emphasize that in a science experiment you need accurate observation, and the students could not assume they knew the answer without looking carefully. Teacher (talking to the whole class): If you're unsure what the big drips and the small drips do, have another look at that because it might be different than you thought it was going to be. ... have another wee look at it because it might be different than you think.

Guiding the students' understandings and explanations. In order to help them make sense of the experiment, the students needed to be reminded of what they already knew about light and the way light passes through water. The teacher referred to this knowledge in her discussions with each group. For example, in Austin's group she raised the question of what happens when light goes through water

Teacher:	... What happens to light when it goes through water, Paul?
Paul:	Magnified.
Austin:	It magnifies.
Teacher:	Why? What is actually happening to the light when it's going through this water?
Paul:	It makes things go fat.
Teacher:	Why does it make things go fat? What's actually happening to the light?
Austin:	It's refracting through the water.
Rowena:	It's bending.
Teacher:	What's actually happening to the light? Yeah, it is bending but what's actually happening to it? Yep.
Austin:	It's refracting, so it.....
Teacher:	How's it travelling? Does it travel just as fast through the air or through the water?
Rowena:	Slowly.
Teacher:	It travels slowly.

The teacher also wanted the students to learn that a science activity is about testing predictions. When she asked Shaun's group to repeat the experiment, she set it up as a challenge ("I want you to try the big drop and the little drop. Show me that, prove me that, what you've just told me"). Finally, the teacher wanted the students to develop an explanation for what they had observed. With each group, once she had made sure they had the correct results, she challenged them to explain what happened. She did this by suggesting the information they needed in order to develop an explanation. For example, when she had finished helping Austin's group complete the experiment, she raised the question of why?

Teacher:	Okay, why? Have a look at the shape of the little one, have a look at the shape of the big one and think about something you've done a couple of days ago.

Austin:	The big one um, is bigger so you can see it all or something?
Teacher:	Think about, think about the shape of the little one, what's it doing?
Rowena:	It's spread out more.
Austin:	It's curving.
Teacher:	Okay, and this one here's not as curvy is it? It's flatter isn't it, so think about curving, which is it, which curve was it?
Rowena:	Concave.
Paul:	Concave.
Austin:	Convex.
Teacher:	You can have that discussion amongst yourselves and work it out which one. I'm not going to tell you but you think about that, okay.

Taken together, these interactions between the teacher and the students guided the students towards the model or structure of a scientific experiment that the teacher had in mind. This consisted both of a set of procedures (e.g., focused and accurate observing) and ways of thinking about the procedures and results (relating them to previous experiences, predicting and explaining the results). In addition, the teacher maintained her usual classroom management procedures, reminding the students from time to time about the kind of behaviour expected in that classroom.

What the teacher had done, interactively with the students was to develop a set of expectations about how an activity ought to be carried out. She clarified and elaborated what she expected, what she meant by the instructions, what they had to do to succeed in this type of activity.

10.2 The social interaction system

The students' behaviour was also determined by the social relationships that existed and were evolving between the students themselves. The roles played by each student in each group were the product of their previous interactions with each other. The relationship between these role expectations and the requirements of the activity constrained which students carried out which aspects of the procedures, how decisions were arrived at, and who determined and announced the results. There is not space in this paper to detail all the different ways in which the social interactions between the students determined how they carried out and experienced the activity but some examples will serve to illustrate the general principles.

Each of the groups in which Sonya, Shaun, and Austin worked, operated in a different way. Sonya's group was relatively unstable. The students worked independently or in varying pairs rather than all together. Sonya had close relationships with others (Rowena and Kelly) not in the group. Rowena came over and joined Sonya on several occasions and, for the third activity, Sonya left the group to work with Kelly.

Sonya remained on the edge of her group. At the beginning of the activity as she was watching the others carry out the task, she tried to move closer to the action. Jake told her to move away ("Ohhh, don't get so close to me Sonya!). No one person in this group took the role of leader or took responsibility for getting the group to complete the required tasks. Alice had the reputation of knowing what to do in these kinds of activities and whenever Sonya needed help she turned to Alice and believed what Alice said.

Shaun's group worked more effectively largely because one well-informed student (Maurice) took on the role of organising and informing the group about what needed to be done.

Maurice	(reading from instruction sheet): What does this say? Stick your finger in the small jar look to see how big it appears.
Shaun	(taking the jar): I'll go pour water.
Maurice	(taking the jar back off Shaun): Stop. You've got to see how big my finger looks. (Maurice puts his finger in the empty jar).
Patrick:	It looks normal size.
Shaun:	Normal size.
Maurice:	Now go and get water in the glass. Not full. Shaun about so high (indicating with his finger) ... No higher.

Maurice was the only student in the group who understood the purpose of the drop experiment and tried to carry it out effectively. When the group were observing the results of their experiment, he was the one who announced what they had found out. When they needed further information, he was able to supply it.

Maurice:	It happens to light when it goes through water, it slows down, it does. It does, I read it in the book.
Shaun:	Why?
Maurice:	It says the light slows down when it goes through the water.

There was, however, a limit to the extent to which Maurice could take the group with him. Shaun misunderstood the experiment and despite several attempts by Maurice to help him, he never understood the purpose. As a result, there were several occasions when Maurice separated himself from the group and pursued his own agenda. For example, Maurice did not believe that the group's results could be what the teacher intended, so he went individually to the teacher to check them. He explained that the drops "didn't really magnify it much" although the bigger drops "magnified it a bit". The teacher suggested that he should do the experiment again.

For Shaun, understanding the experiment was entangled with his relationship with Maurice. Shaun wavered between wanting to assert his knowledge and independence, and wanting help from Maurice. In the following example, both Shaun and Maurice are reading the instructions and trying to work out what they need to do the experiment.

Shaun (reading instructions aloud to self): Small, piece of wax paper ... Water.

Maurice: Water, a book.

Shaun reaches for the jar to go and get water.

Maurice grabs it back.

Maurice: Stop. Don't get water yet 'cause it will say how ...

(Shaun holds the magnifying glass up and looks at the ceiling through it.)

Maurice: Get a book. Get a book, Shaun.

Shaun: Why me?

Maurice: 'Cause...

(Shaun walks over to the bookshelf on back wall of the classroom, looking through the magnifying glass as he walks.)

Although Shaun tried to assert his independence by taking the jar to get water, Maurice stopped him and ended up ordering him to go and get a book. Shaun tried to retain his dignity by looking at the ceiling and around the classroom through a magnifying glass.

In each of the groups, the relationships between the students, the match or mismatch between their respective roles and status, their abilities to negotiate help or co-operation between each other, and the tensions between their need to work together within the group and their need to sustain their relationships with others outside the group, all shaped how the activity was carried out.

10.3 The student's own skill and knowledge system

During the course of an activity, the nature of the student's involvement in the activity is both determined by, and changes, the student's repertoire of background knowledge, skills, expectations, beliefs, attitudes, and feelings. As the activity evolves, so does this internal cognitive and emotional system. The progressive evolution of this system constitutes the learning process. In previous reports, we have suggested that all aspects of the learning process form a coherent system involving changes in students' knowledge, beliefs, attitudes, and feelings (cf. Alton-Lee, Nuthall, & Patrick, 1993; Nuthall 1999b).

In the water-drop activity, each of the students brought to the activity different levels of interest, knowledge and skill. Sonya was not interested in the topic and engaged in the activity primarily for the purpose of completing the report. She and her friend Kelly kept monitoring how quickly they were getting through their reports.

Sonya (to Kelly) I'm nowhere near finished.

Kelly: (inaudible) find out about.

Sonya: I'm up to why I think this happened - nearly. Just need to write this then I'm onto it.

When Sonya came to the place in her report where she had to record the results of the experiment, she realised that she did not know what to write. So she and Alice repeated the experiment quickly for the sake of getting something to write. Consequently, Sonya wrote down the wrong result. "... when we put drops of water the little drops made the words go blurry and the big drops made the words go ..."

Later when the teacher helped the group carry out the experiment carefully and correctly, Sonya realised she had written the wrong answer in her report, but she decided not to correct it. Instead she moved on to explaining why it happened and asked Alice what to write.

Sonya: I don't know why I thought ... I don't know why I think this happened. ... Why did it happen?

Alice: Because of refraction (inaudible) the finger magnifies it (inaudible).

Sonya: Oh, okay.

So Sonya wrote "Why I think this happened. Because of refraction". Sonya, however, believed that refraction meant reflection. Because Sonya's focus was on completing the report, and not on understanding the experiment, she remembered how she finished the report but not what she had written. A few days after the unit was finished, Sonya was asked to look at a video-clip of this incident and talk about what was happening.

Interviewer: At this stage what are you feeling?

Sonya: I don't know why?.

Interviewer: You don't know why?. Is it worrying you?

Sonya: No. 'Cause I like to have my work finished by the end of the day and if I don't know ...

Interviewer: If you don't know why, you won't have it finished.

Sonya: Yeah.

Interviewer: You won't know what to write?

Sonya: Mmm. Oh, I was stuck on that question for a wee while. ...

Interviewer: Right. Did you get an answer to the 'why?' question do you think?

Sonya: Mmm. Yes. But I ...

Interviewer: Do you remember?

Sonya: No. I don't remember what it was.

Sonya never understood the principles behind the activities in the unit. When she was asked if she could explain how light is affected when it passes through water, she could recall what was said, but not what it meant.

Sonya: Oh, 'cause we were answering a question and Krista was asking Alice like what did it mean and she told us it was something to do with the air and the water ... I'm not sure who, someone in our group said something to do with the air and the bending of the light so it makes the ...

Interviewer: ... Still doesn't quite make sense to you though does it?

Sonya: No. ...

Although Shaun was interested in the purpose of the experiment, he had little confidence in his own knowledge. Like Sonya, Shaun had someone in his group that he could depend on for answers. For example, Maurice had provided Shaun with the answers to the study questions in the previous activity.

Maurice (reading the questions): Okay, does your finger look bigger when it is in a jar of water? Why?

Shaun: Why?

Maurice: Because it's being ... magnified.

Shaun: Magnified.

Maurice: Cool, its being magnified. It happens to light when it goes through water, it slows down, it does. It does, I read it in the book.

Shaun: Why?

Maurice: It says the light slows down when it goes through the water.

However, this created problems for Shaun during the drop activity. Shaun was very concerned about getting his report right. Once he started to write his report it became the focus of his attention to the extent that he failed to hear the teacher talking about what they should be doing. Aware that Maurice probably knew all the answers, Shaun looked across and read Maurice's report whenever he could.

Shaun mistakenly believed that the purpose of the drop activity was to look at drips of water through a magnifying glass. He had confused the instructions for the drop activity with the instructions for the next activity that involved using a magnifying glass. Each time his group carried out the drop experiment, Shaun looked at the drops through his magnifying glass. As a consequence, he made several mistakes in his report. He realised the significance of these mistakes by looking at Maurice's report and seeing that it was quite different from his. This upset him to the point that he started crying quietly to himself and despite help from the teacher ("Don't worry about it, it's not worth worrying about. What do you think you've done wrong Shaun? What bit do you think you've done wrong? It's not worth worrying about Shaun, okay?") and from Maurice, he stopped participating in the group and did not see what happened when the teacher helped the group do the experiment again. While Maurice was responsible and generally helpful in the group, Shaun found the comparison between Maurice's work and his own deeply upsetting.

When he was interviewed two weeks later, Shaun still misunderstood the activity. When he was asked about how he had used a magnifying glass he described the drop experiment.

Interviewer: Did you use one (a magnifying glass) in class?

Shaun: Yeah. We did. We looked um, we looked at tiny little writing and that and um, and then when we dropped the bit of water on the gladwrap and looked at it ...

Interviewer: What did you learn from that I wonder?

Shaun: That when you're looking through a magnifying glass, it makes it look bigger and more clearer to see.

When he was asked to explain why this effect occurred, he was unable to provide any explanation.

Interviewer: But why does it do it do you think? What happens to the light going through? Why would a magnifying glass make things look bigger?

Shaun: Probably because it's magnifying.

Interviewer: Have you ever thought why a bit of glass would actually magnify something? What's happening? ...

Shaun: No, not really ... It's like that in glasses. Like Jerry's wearing.

Shaun had some sense of how light was affected by water, but this was based on his previous out-of-school experiences of light being reflected off the surface of water. When he heard in class that light was bent by water, he assumed that this meant reflection.

Although Shaun was involved in the activity with the others in his group, looked closely at Maurice's report, he found the experience emotionally upsetting and never understood the purpose of the experiment or learned the reason why a drop of water acts like a magnifying glass.

Austin played a leadership role in his group. He started the activity with more background knowledge so that when the teacher joined his group to talk about what happens to light when it passes through water, he contributed to constructing an explanation. Perhaps because of this background knowledge, Austin was active in helping his group carry out the experiment, organising the materials, and participating in the observations.

Austin: Okay, we need to put a drop of water on it. ... It doesn't look any different.

Rowena: It does so! Look. Its' magnifying

Austin: Don't (inaudible).

Rowena: See look, it looks bigger.

Austin: I see.

Rowena: It makes things, um, bigger. It magnifies them ... It magnifies it, that's an effect. An effect, yep, magnifies it.

Austin: Makes it bigger and blurry, big and blurry. Okay.

Later, the group realised they had not compared two different sized drops, so they did the experiment again, reaching the wrong conclusion that the bigger drop magnified more. When Austin was writing his report and got to the point of explaining the effect ("Why I think this happened") he seemed puzzled and did the experiment again by himself. Later when the teacher joined the group and helped them get the right result, she invited them to find out why the water drops magnified.

Teacher: Okay, why? Have a look at the shape of the little one, have a look at the shape of the big one and think about something you've done a couple of days ago.

Austin: The big one um, is bigger so you can see it all or something?

Rowena: It's spread out more.

Teacher: Think about the shape of the little one, what's it doing?

Austin: It's curving.

Teacher: Okay, and this one here's not as curvy is it? It's flatter isn't it, so think about curving, which is it, which curve was it?

Rowena: Concave.

Paul: Concave.

Austin: Convex.

Throughout this activity, Austin was involved, informed and thinking about what was happening. As a result he almost managed to create an explanation for the effect by bringing together all that he had learned. In his report wrote:

I think that this happened because light travels slower through water than air. The drips were like a convex lens and curved outwards so it was magnified.

It should be clear from this analysis of what and how each student learned from the activity that the story of their individual learning is intricately and continuously entangled with their social interactions within their groups. However, how the three students interacted with others in their groups did not determine how or what they learned. However busy or involved they were in carrying out the activity, the learning took place within their personal cognitive-emotional system. Understanding what each student learned requires information about their background knowledge (especially misconceptions) and the content of their encounters with the information embedded in the activity.

11. Discussion and Conclusions

This article started with the claim that, in lieu of anything better, the busy, active classroom (in which students are continuously engaged in learning activities) has been idealised as the model of effective teaching. It is the model that is studied, emulated and rewarded. Underlying this model is the implicit theory that learning is the automatic consequence of on-task behaviours, whatever the nature of the task.

We know, however, that students are socialised into playing the role of the busy active learner. They can learn to look interested and involved while finding ways to minimise effort and disengage their minds. They can learn to produce the products of learning activities without engaging in the learning that the activities were designed to create (Weade, 1992).

What is needed is an understanding of the learning process that can be used to design activities and manage student involvement with those activities in ways that really do engage student minds. What are the essential characteristics of a learning activity, or of student behaviour, that will ensure that significant learning is taking place.

What has emerged from the analysis of our data is that there are two closely related but distinct kinds of learning that we need to take account of. First, there is the learning of the curriculum content - the knowledge, beliefs, concepts, skills and attitudes that make up specific curriculum areas. These are the intended outcomes of specific learning activities. In our studies, these are the concepts, beliefs, skills , and attitudes that teachers intend their students to acquire from their science and social studies activities.

Second, there is the more general learning of those cognitive structures and processes that determine how curriculum learning occurs. It is these structures and processes that shape the ways in which students' minds perceive, interpret and process experience. Piaget describes them as intelligence. Vygotsky and Leontiev describe them as the higher mental processes. In this article I have described the acquisition of these structures and processes as the shaping of student minds.

It is important to understand that these two kinds of learning occur simultaneously. As students acquire curriculum content, their minds are being furnished or shaped by both the curriculum content and the experiences and contexts that embed that content. The knowledge they acquire is not disembodied. It comes entangled with the sociocultural context and activity through which it is encountered.

This means that, in order to understand what students learn we need to analyse both how they are acquire curriculum content and also the learning activities through which the acquisition occurs. The nature of the classroom as a socially and culturally structured community is as much part of the curriculum as the intended curriculum objectives.

In this article, I have identified the highly individual nature of what students learn of the curriculum content. Differences in what students learn are not the result of differences in their academic abilities but in differences in the ways they experience and participate in classroom activities. Those students who learn more than other students do so because of the ways in which they choose and create their own learning experiences. The relationship is not, however, a simple causal one. Those students who are more likely to create their own learning experiences are those students who already know more, are more interested in the topic, and manage their engagement in learning activities more effectively.

For this reason it is essential that we understand how students participate in learning activities. If, as I have argued, learning activities are both the occasion for learning curriculum content and the model for the structures and processes that come to furnish student minds, then it is important to know exactly how students experience those activities.

We need to know what determines how students participate in classroom activities and what is the expertise that students acquire as they learn to manage their participation? This article has attempted to answer these questions by analysing the structure and processes that make up typical classroom activities. An analysis of the participation of three students (and their groups) in the same science activity in a Year 5/6 classroom suggested that the activity consisted of four tasks: the instructions, carrying out the activity (following the instructions), writing a report, and discussing the results. The way these four tasks related to each other, and the way they were carried out, depended on the students' involvement in three different contextual systems. These were: the instruction-evaluation system, the peer interaction and relationship system, and the personal knowledge and skill system.

Tracing the behaviours and experiences of the three individual students shows that the three systems are intricately and continuously related to each other. They are, as it were, each other's contexts (Van Oers, 1998).

In order to become expert in classroom activities of this type, the student must learn how to work within each of these systems. Specifically, this means developing an internal model of how each of these systems operates and of how they interact with each other so that the student can both predict, and where this is possible, manage, effective participation in these systems.

For example, if the student is to become an expert at working within the instruction-evaluation system, the student needs to develop an internal model of what the teacher expects. This will allow the student to participate in ways that gain the teacher's approval, and where necessary, for personal reasons, play the 'game' of being a good student without actually fulfilling the teacher's requirements. Whenever a student does not have the curriculum knowledge or skill to fulfil the requirements of an activity as the teacher expects, the student who has internalised an effective model of this system can plan an alternative way of meeting the teacher's requirements that does not expose the student's lack of knowledge or skill.

Similarly, a student who wishes to negotiate a different relationship with another student not only needs expertise in the social relationship system, but also needs to know how to give the appearance of being simultaneously continuously engaged in the learning activity.

The conclusion this leads to is that those who learn most from their classroom experiences are those who are most expert in the contextual systems that determine how classroom activities are carried out. They are the students who are most likely to take leadership roles in group activities, skilfully managing the social process so that it serves their needs. They are the students who have the best understanding of the ways teachers like classroom activities to be carried out. They understand what is implied by what teachers say and do. They are the students who understand their own cognitive processes and can negotiate and manage their participation in classroom activities in ways that match their skills and knowledge. Because of their expertise, these are also the students who are most likely to be rewarded for their participation in classroom activities. They are the ones who will seem to the teacher to be the most able and the most hard-working.

It is these students who are most likely to select alternative activities or create additional learning experiences that will enhance their learning both of the curriculum content and of the structures and processes that make up classroom activities. It is this effect that is evident in the data in Figures 1, and 2, and Table 4 above.

If this analysis of the relationships between student learning, participation in classroom activities, the acquisition of cognitive processes, and academic aptitude, is approximately correct, then teachers need to pay close attention to the structure of classroom activities and how they manage student participation in those activities. The science activity analysed in this paper was taken from a highly regarded book of science activities published for teachers. The activity was closely managed by the teacher. She monitored how the students were working together in their groups, how they were following the instructions and using their materials, and how they were interpreting the experiment. She interacted with them constantly, reminding, guiding, modelling, correcting, and admonishing. Most of the students most of the time were actively engaged in the experiment. Even so, a significant number of the students misunderstood the purpose and the results of the experiment.

There were several reasons for this. Individually, some students lacked the relevant background knowledge or failed to connect the experiment with the relevant background knowledge they had. They were confused about how light works and consequently how to make sense of what they were doing. Socially, the groups lacked coherence. Friendship patterns conflicted with group membership. What counted as success in the peer culture conflicted with what the teacher counted as success. What counted as interacting together effectively in the peer culture conflicted with how the teacher expected the students to work with each other. The students past history with activities of this kind meant that they focused on completing the written report before they had satisfactorily completed the experiment.

The purpose of this paper is not to blame the teacher. It is to help clarify the relationship between teaching and learning by drawing on the research we have done on individual student experiences during typical classroom activities. It is an initial attempt to bring together into a coherent analysis all of the different factors that determine how students experience classroom activities. If it is the internalisation of classroom activities that determines both what students learn and how they learn, then we need to understand exactly what it is that students are internalising, and how teachers can manage and facilitate that process.

Note

1. The tests used to assess each student's academic aptitude were the Progressive Achievement Tests (Reid, Jackson, Gilmour, & Croft, 1981)that the school administered as part of their assessment programme. The percentile score used to report each student's academic aptitude was the average of percentile rank for age on at least three tests. These usually included tests of reading comprehension, listening comprehension, and scholastic ability. The PAT Reading Comprehension has a relatively high correlation with teachers' ratings of scholastic ability ($r = 0.78 - 0.88$, Reid, et al., 1981) and a high loading on a general intelligence factor (Hattie, 1979).

Acknowledgements

The data on which this article is based comes from the Project on Learning funded by the 3 year grant from the Marsden Fund. I would like to gratefully acknowledge the continuous technical support provided by Roger Corbett, the administrative assistance of Anthea Clibborn-Brown, and the endless hours of transcribing that have been carried out by Lynn Ward, Kathy Renton, and Anthea Clibborn-Brown.

References

Alton-Lee, A.G., & Nuthall, G. A. (1990). Pupil experiences and pupil learning in the elementary classroom: an illustration of a generative methodology. *Teaching & Teacher Education, 6,* 27-45.

Alton-Lee, A.G., Nuthall, G. A., & Patrick, J. (1993). Reframing classroom research: A lesson from the private world of children. *Harvard Educational Review, 63* (1), 50-84.

Bellack, A.A., Kliebard, H.M., Hyman, R.T., & Smith, F.L. (1966). The language of the classroom. Teachers College, Colombia University, New York: Teachers College Press.

Benenson, J., Apostoleris, N., & Parnass, J. (1998) The organization of children's same-sex peer relationships. In Bukowski, W. M., & Cillessen, A. H. (Eds). *Sociometry then and now: Building on six decades of measuring children's experiences with the peer group* (New directions for child development, No. 80), (pp. 5-23). San Francisco: Jossey-Bass

Berkenkotter, C. & Huckin, T.N. (1995). *Genre knowledge in disciplinary communication: Cognition/culture/power.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Bransford, J., Sherwood, R., Vye, N. & Reisser, J. (1986). Teaching thinking and problem solving: Research foundations. *American Psychologist, 41,* 1078-1089.

Brewer, W. F., & Nakamura, G. V. (1984). The nature and functions of schemas. In R.S. Wyer & T.K. Srull (Eds.), *Handbook of social cognition* (Vol.1, pp.119-160). Hillsdale, N.J.: Erlbaum.

Brophy, J. & Good, T. (1986).. In M.C. Wittrock (Ed.), *Handbook of research on teaching* (3rd ed., pp. 570-602). New York: Macmillan. Brown, A.L. (1994). The advancement of learning. Educational Researcher, 23 (8), 4-12.

Brown, A.L., & Campione, J.C. (1994). Guided discovery in a community of learners. In K. McGilly (Ed.), *Classoom lessons: Integrating cognitive theory and classroom practice* (pp. 229-270). Cambridge MA: MIT Press/Bradford Books.

Cahan, S. & Cohen, N. (1989). Age versus schooling effects on intelligence development. *Child Development, 60,* 1239-1249.

Christie, F. (1989). Language development in education. In R. Hasan, & J.R. Martin, (Eds.), *Language development: Learning language, learning culture.* Vol, XXVII, *Advances in discourse processes,* (pp. 152-198). Norwood, NJ: Ablex Publishing.

Clark, C.M. & Peterson, P. L. (1986). Teachers' thought processes. In M.C. Wittrock (Ed.), *Handbook of research on teaching* (3rd ed., pp. 255-296). New York: Macmillan.

Cole, M. (1996). *Cultural psychology: A once and future discipline.* Cambridge, Mass: Harvard University Press.

Dahloff, U., & Lundgren, U.P. (1970). *Macro- and micro-approaches combined for curriculum process analysis: A Swedish educational field project.* Goteberg, Sweden: University of Goteberg, institute of Education.

Derry, S.J. (1996). Cognitive schema theory in the constructivist debate. *Educational Psychologist, 31* (3/4) 163-174.

Dochy, F., Segers, M., & Buehl, M.M. (1999). The relation between assessment practices and outcomes of studies: The case of research on prior knowledge. *Review of Educational Research, 69,* 145-186.

Doyle, W., & Carter, K. (1984). Academic tasks in classrooms. *Curriculum Inquiry, 14*(2), 129-149.

Gergen, K.J., & Davis, K.E. (Eds.) (1985). *The social construction of the person.* New York: Springer Verlag.

Green. J.L., & Dixon, C.N. (1993). Talking knowledge into being: Discursive and social practices in classrooms. *Linguistics and Education,* 5, 231-239.

Haenen, J. (1996). *Piotr Gal'perin: Psychologist in Vygotsky's footsteps.* New York: Nova Science Publishers.

Hattie, J. (1979). A confirmatory factor analysis of the PAT: Reading comprehension, reading vocabulary, and listening comprehension. *New Zealand Journal of Educational Studies,* 14, 172-188.

Jackson, P. (1968). *Life in classrooms.* New York; Holt, Rinehart & Winston.

Jones, A. (1985). Which girls are learning to lose? Gender, class, and race in the classroom. *New Zealand Women's Studies Journal, 1*(2), 15-27.

Kollar, G., Anderson, C., & Palincsar, A. (1994). *Power, status, and personal identity in small group problem solving.* Paper presented at the Annual Conference of the National Association for Research in Science Teaching, Anaheim, California.

Ladd, G. W. (1999). Peer relationships and social competence during early and middle childhood. Annual-Review-of-Psychology, 50, 333-359.

Leont'ev, A.N. (1981). The problem of activity in psychology. In J.V. Wertsch, (Ed.) *The concept of activity in Soviet Psychology* (pp. 37-71). Armonk, New York: Sharpe

MacKay, D.A., & Marland, P.W. (1978, March). Thought processes of teachers. Paper presented at the Annual Meeting of the American Educational Research Association, Toronto, Canada.

Martin, J.R. (1992). *English text : System and structure.* Philadelphia: John Benjamins.

McDonald, G. (1998). *The birthdate effect and the demography of the classroom.* Paper given at the Annual Conference of the New Zealand Association for Research in Education, Dunedin, New Zealand.

McNair, K. (1978). Capturing inflight decisions: Thoughts while teaching. *Educational Research Quarterly, 3* (4), 26-42.

Morrison, F.J., Smith, L. & Dow-Ehrensberger, M. (1995). Education and cognitive development: A natural experiment. *Developmental Psychology, 31,* 789-799.

Nelson, K. (1996). *Language in cognitive development: The emergence of the mediated mind.* New York: Cambridge University Press.

Nuthall, Graham (1999a). Learning how to learn: the evolution of students' minds through the social processes and culture of the classroom. *International Journal of Educational Research, 31* (3), 139 - 256.

Nuthall, G. A. (1999b). The way students learn: Acquiring knowledge from an integrated science and social studies unit. *Elementary School Journal,* 99, 303-341.

Nuthall, G. A. (2000a). The role of memory in the acquisition and retention of knowledge in science and social studies units. *Cognition & Instruction, 18* (1) 83-139

Nuthall, G.A. (2000b) The anatomy of memory in the classroom: Understanding how students acquire memory processes from classroom activities in science and social studies units. *American Educational Research Journal,* 36 (4)

Nuthall, G.A. & Alton-Lee, A.G. (1993). Predicting learning from student experience of teaching: A theory of student knowledge construction in classrooms. *American Educational Research Journal. 30,* 799-840.

O'Connor, M.C. & Michaels, S. (1996). Shifting participant frameworks: Ochestrating thinking in group discussion. In D. Hicks (Ed.) *Discourse, learning, and schooling (pp. 63-103).* New York: Cambridge university Press.

Piaget, J. (1962). *Play, dreams, and imitation in childhood.* New York: Norton.

Piaget, J. (1978). *Success and understanding.* London: Routledge & Kegan Paul.

Ramsay, P., & Oliver, D. (1995). Capacities and behaviour of quality classroom teachers. *School Effectiveness and School Improvement, 6,* 332-366.

Reid, N.A., Jackson, P., Gilmore, A., & Croft, C. (1981). *Test of scholastic abilities: Teacher's Manual.* Wellington: New Zealand Council for Educational Research.

Rogoff, B. (1995). Observing sociocultural activity on three planes: Participatory appropriation, guided participation, and apprenticeship. In J. V. Wertsch, P. del Rio, & A. Alvarez (Eds.) *Sociocultural Studies of Mind* (pp. 139-164). New York: Cambridge University Press.

Rogoff, B., Matusov, E., & White, C. (1996) Models of teaching and learning: Participation in a community of learners. In D. Olson & N. Torrance (Eds.), *Handbook of education and human development: New models of learning, teaching and schooling,* pp. 388-414. Oxford: Blackwell.

Russell D. R. (1996). *Rethinking Genre: An activity theory analysis.* Paper given at the NCTE Vygotsky Centennial Conference, Chicago, 1996.

Sharp, D., Cole, M., & Lave, J. (1979). Education and cognitive development: The evidence from experimental research. *Monographs for the Society for Research in Child Development,* 38 (5, No. 152).

Snyderman, M., & Rothman, S. (1987). Survey of expert opinion on intelligence and aptitude testing. *American Psychologist,* 42, 137-144.

Stigler J.W., & Hiebert, J. (1999). *The teaching gap: Best ideas from the world's teachers for improving education in the classroom.* New York: The Free Press.

Van Oers, B. (1998). From context to contextualising. *Learning & Instruction,* 8(6), 473-488.

Vygotsky, L.S. (1978). *Mind in society: The development of higher psychological processes.* (M. Cole, V. John-Steiner, S. Scribner, & E. Souberman, Eds.) Cambridge, MA: Harvard university Press.

Vygotsky, L.S. (1981). The genesis of higher mental functions. In J.V. Wertsch (Ed.), *The concept of activity in Soviet psychology* (pp.148-188). Armonk, NY: Sharpe.

Weade, G. (1992). Locating learning in the times and spaces of teaching. In H.H. Marshall (Ed.) *Redefining student learning: Roots of educational change* (pp.87-118). Norwood NJ: Ablex Publishing.

Wells, G. (1994). Text, talk and inquiry: Schooling as semiotic apprenticeship. In N. Bird, et al. (Eds.), *Language and Learning.* Hong Kong: Institute of Language in Learning.

Wells, G. (1999). *Dialogic inquiry: Towards a sociocultural practice and theory of education.* New York: Cambridge University Press

Wertsch, J.V., Minick, N., & Arns, F.J. (1984). The creation of context in joint problem solving. In B. Rogoff, & J. Lave, (Eds.) *Everyday cognition: Its development in social context.* Cambridge: Cambridge University Press

Anschrift des Autors:
Graham Nuthall
Education Department
University of Canterbury
Private Bag 4800
Christchurch, New Zealand
E-mail: G.Nuthall@educ.canterbury.ac.nz