How do children, individually and collectively, make meanings of their learning experiences?

How can teachers become aware of children’s meaning making on an ongoing basis?

Is it possible and useful to create an integrated theory of student learning?

How can classroom research enhance critical understandings of the situated nature of learning and teaching, while taking into account the systemic and educational policy contexts?

How do differences, such as class, race, culture, gender and sexualities, interact with student learning?

How can teachers respond effectively to the realities of today’s diverse classrooms?

What are the current and emerging issues in classroom research?

These are just some of the questions this book grapples with. It pays tribute to Professor Graham Nuthall’s (1935–2004) research contributions – a pioneering and internationally renowned classroom researcher of teaching and learning from New Zealand. It has been written by emerging and experienced classroom researchers from several countries as part of a project aimed at building on and extending Nuthall’s research and promoting the conducting, teaching and supervision of classroom research. The authors engage critically with theoretical, methodological and pedagogical possibilities of their research using Nuthall’s work as a springboard. As a result, all authors make links between theory and practice. Further, several leading international researchers contribute comments on future directions for classroom research and its relevance for teaching and learning.

Understanding teaching and Learning: Classroom Research Revisited would be of interest to practicing or prospective teachers and teacher educators, as well as scholars and students of teaching and learning.
Understanding Teaching and Learning
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Front cover picture: “Maths is everywhere. It’s in the sky, in the volcano and under the sea.” *A drawing by 10-year-old Zach* (pseudonym). From database for doctoral dissertation on Children’s Beliefs about Mathematics collected by Catherine Solomon. Used with permission of the school and the child.

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FOREWORD

In 2004 I was fortunate to be granted a fellowship to study at the University of Canterbury in Christchurch, New Zealand. One of the highlights of the fellowship was to be the opportunity to meet and talk with Professor Graham Nuthall, a scholar who had, for four decades, been working on the problem of tracing the relationship between teaching and learning. For those of us who are instructional researchers, understanding this relationship is core to our work and the complexities of this enterprise are only too familiar. Professor Nuthall, working with his university and teacher colleagues, was “ahead of his time” in exploring innovative technologies and techniques for gathering and analysing evidence about this relationship.

For all these reasons, these were conversations I was eager to have with Professor Nuthall. In particular, I was heavily engaged in the study of children aged five to ten years in classroom-based guided inquiry science and I was curious to know what he would think of our efforts to identify the advanced teaching practices that seemed critical to the engagement and achievement of atypical students in these classrooms. Before I arrived to begin my fellowship, Professor Nuthall became critically ill and there was no longer the possibility of our meeting.

Seven years later, as I read this volume, it occurred to me that I was having a rare vicarious experience—eavesdropping, if you will, on exchanges between a community of scholars and Professor Nuthall. What unites this community is its commitment to understanding and enhancing learning in classrooms. In her invitation, editor Baljit Kaur encouraged the authors to engage critically with the theoretical, methodological and pedagogical aspects of Professor Nuthall’s scholarship. Furthermore, Dr Kaur urged the authors to “look ahead” rather than merely engaging in the ideas with which Professor Nuthall was already working.

Indeed, the authors have been responsive to these charges. As a consequence, this volume is rich with ideas, including: critiques and elaborations of the theories with which Professor Nuthall worked; proposals regarding additional features of instruction (such as domain-specific demands) that might figure in classroom research and assessment; questions about the application of his scholarship to more diverse populations of students; and models to attain a better representation of the individual in the social/cultural milieu of classrooms and schools.

I cannot imagine a better way to honour the contributions of this important scholar. From all accounts, and from what I have ascertained from his writing, Professor Nuthall recognised how ambitious his agenda was and was modest about his efforts to describe and explain the complex and multi-tiered interaction of teaching and learning. I think that he would have been thrilled that his ideas were taken in such earnestness and challenged so respectfully. The composite agenda proposed by the authors of this volume stands as a precious legacy of his work.

Annemarie Sullivan Palincsar
University of Michigan
July 2011
ACKNOWLEDGEMENTS

I am grateful to the contributing authors for their enthusiastic uptake of the collaborative spirit of this project to showcase and promote classroom research on teaching and learning. All of them gave their time generously by participating in various activities associated with the project—the workshop, the symposium as well as the timely review of chapters—that culminated in this book. My sincere gratitude goes to Greta Morine-Dershimer and Alison Gilmore for their advice throughout this project. I am also indebted to Adrienne Alton-Lee, Wally Penetito and Judith Green for their contributions in making the symposium a resounding success through their presentations and participation. I am thankful to the Graham Nuthall Classroom Research Trust for funding this project. Jill Nuthall, Peter Allen, Jane McChesney and Keryn Davis were particularly helpful in organising the symposium and always willing to respond promptly to my requests for help. Administrative and logistical assistance sanctioned by Greg Lee, the then Head of the School of Educational Studies and Human Development at the University of Canterbury, and gladly provided by Tina Frayle, Anne Guy, Kathleen Ell and Kirsty Fraser, is gratefully acknowledged. Deb Hill worked with a great deal of humour to help me prepare the proposal for prospective publishers, and suggested the subtitle for the book. I feel fortunate to have the keen backing of my work from Jean McPhail, Kathleen Quinlivan, Fleur Harris and Sukhdeep Gill who repeatedly step up to the plate irrespective of the nature of the task or the unwieldy timeframes of my requests. Editorial expertise of Tanya Tremewan and Jenny Heine could not have come at a more opportune moment and has been crucial for completing this project. My appreciation goes to Peter de Liefde at Sense Publications who liked the idea of this book and decided to proceed with its publication. Finally, I deeply appreciate the encouragement and affirmation I receive from Avtar Chauhan for pursuing my work uninterrupted.

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INTRODUCTION

*Understanding Teaching and Learning: Classroom Research Revisited*

BALJIT KAUR

The ‘classroom’ is a curious and amorphous discursive space, therefore—expanding and contracting under the pressures of different discourses that police its boundaries and construct its interiority in disparate ways. Warm, womb-like, nurturing. Overheated, insular, stifling. Or the no nonsense heartland of education, where (real) teachers teach, children learn and researchers ought to, but don’t, research. (MacLure, 2003, p. 16)

Classrooms, despite being cultural inventions of the eighteenth and nineteenth centuries, still hold important lessons for understanding the nature of teaching and learning that most students in the twenty-first century experience. As instructional researchers, we are aware that teaching and learning are not confined to the classroom contexts; far from it. However, as Vygotsky reminds us, the nature of instructional learning that occurs within a formal classroom setting is significantly different from that taking place as a part of students’ everyday lives in a given cultural context (Vygotsky, 1962). It is the former that primarily concerns the contributors of this volume, including Professor Graham Nuthall, whose research serves as both an anchor and a springboard for this book.

Historically, classrooms were meant to be quite simple in their function and structure—spaces where students of roughly the same age and similar abilities could be grouped together and instructed by a teacher or older student ‘monitors’ to acquire the basic skills of literacy and numeracy. The object was to keep the “children of the poor” off the streets thereby ensuring the safety of the “better” classes (Kaur, 2004; May, 2005; Nasaw, 1979). The instruction was intended to be teacher dominated. Students, mostly boys to begin with, had to learn, to obey and to be disciplined. Those who could not cope with the demands failed or left.

In some ways little has changed over the two centuries of mass public schooling except for its unprecedented expansion. Today, classrooms are a pervasive cultural phenomenon the world over. Despite developments in the use of information technology and online learning resources, they seem likely to endure as sites for teaching and learning—either as the traditional physical contexts or virtual sites, “classrooms of the mind” one may say. Within present day classrooms, students of similar ages are still often placed in one grade and tested against norms that are seen to be relevant for their age level. Those deemed to be of similar abilities get tracked within the classroom, if not segregated.
However, the role of teachers has gone through drastic shifts. Their task has expanded well beyond the basic skills of literacy and numeracy to encompass social transformation towards a more just and inclusive society. Their authority is not absolute, though class management and control remain paramount in teacher training. Meanings attributed to learning have also undergone change. Learning is not just about acquisition; it is meant to be about participation. And there is an increasing emphasis on catering effectively to students from diverse backgrounds and different abilities within the classroom without “othering” them. As MacLure states above, there are multiple discourses about classrooms that intersect with one another. We now understand classrooms as the contested ground where a myriad of contradictory demands from the society, the education system and the teaching profession often collide with each other, and with the ever-changing situated realities of the everyday lives of students and teachers. Students and teachers arrive in classrooms with their unique experiences—collective and individual, historical and current—that shape their interactions with one another and with the learning tasks and activities. We know that students do not learn only what the teacher intends or plans for their learning. Students’ learning is equally and at times more readily influenced by their peers or by what they individually might decide or be able to take up. Even those students who might appear similar in terms of age and ability may have very different learning profiles within the same classroom and across different topics and different times of the day or the year. Given the complexity of classrooms, it is no wonder that researching classrooms has become a vast field of inquiry, different aspects of which are studied from a multitude of theoretical perspectives and methodological approaches.

Three years ago, the Graham Nuthall Classroom Research Trust decided to fund a project that aimed at strengthening the capacity for classroom research at the University of Canterbury in New Zealand, where the late Professor Graham Nuthall had pioneered classroom research and carried it out for over four decades. Through facilitating the exchange of ideas between emerging and experienced classroom researchers from New Zealand and other countries over a two-year period, we aspired to create a research network for mutual support and critical engagement, so as to build on and extend Nuthall’s work, and promote the undertaking, teaching and supervision of classroom research in New Zealand and elsewhere. The invited researchers included those who have been highly influenced by Nuthall’s research as well as those who draw on different theoretical perspectives. The mix of contributors was a deliberate attempt to encourage and mentor a new generation of critical researchers of classroom interactions. As noted above, researchers from varying theoretical perspectives investigate different aspects of classrooms. It is important for researchers to dialogue with each other across their different approaches if we are to generate an adequate knowledge base and stronger explanatory theories of how teaching and learning can be more effective for all students. This book is a material outcome of this aspiration.

Two of Nuthall’s unpublished articles were made available to the invited researchers. Their mandate was to engage critically with theoretical, methodological and/or pedagogical possibilities of their own research using
Nuthall’s work as a springboard. In addition, a number of researchers were asked to contribute brief comments reflecting on future directions for classroom research. Working within a particular frame or on a particular aspect of the classroom can often limit one’s view of the possible options or priorities for further investigation. Given the intricacy of classroom life and the multiple ways in which it is studied, it is necessary to elicit views on potential research directions from different perspectives so as to expand our collective thinking about issues and questions future researchers might need to consider.

A number of opportunities were created for formal and informal interactions between the contributing authors as well as with a wider audience. A one-day workshop began the process of networking between the contributing authors. The discussions, held at the beginning of December 2009, involved teleconferencing links among 20 contributors from Canterbury, another university in New Zealand and several international authors. The discussions in the forenoon centred on questions such as: what constitutes classroom research, how is knowledge about classrooms constructed, and what touchstones or criteria are used for deciding what is “good” classroom research? In the afternoon, the Canterbury-based researchers used the locogram, an experiential group action method, to identify the influential researchers in their own work and place themselves as researchers on the map of classroom research (Dayton, 2005, p. 112). Most of the contributors read the chapters of fellow authors over several months in 2010 and gave feedback to them. In August 2010 a three-day symposium was organised to provide opportunities for a wider exchange of ideas among the contributing researchers and other classroom researchers as well as teachers. A number of authors presented a symposium at the 2011 annual meeting of the Invisible College in New Orleans.

Based on feedback from the one-day workshop, a website was created in early 2010 to encourage informal interactions among contributors. The purpose was not only to encourage dialogue around their current writing for this book but also to help create a community of practice where classroom researchers share their work and ideas in general. However, there was little uptake of this venue for discussion. The reasons might have been the competing demands from other aspects of professional and personal lives, lack of direction or focus, or a combination of these and other exigencies. Our vision of creating a vibrant and active network of classroom researchers, particularly at Canterbury, has not come to fruition as envisaged. And yet, a beginning has been made. As Annemarie Palincsar notes in her Foreword, “… as I read this volume, it occurred to me that I was having a rare vicarious experience—eavesdropping, if you will, on exchanges between a community of scholars and Professor Nuthall. What unites this community is its commitment to understanding and enhancing learning in classrooms” (p. v). Various opportunities to promote dialogue, outlined above, increased interactions among several contributors and provided many of them with their first opportunities to share their research with fellow researchers and teachers. If this book gives impetus to continuing dialogue about classroom research among its readers, it will have served its purpose.
ORGANISATION OF THE CONTENT

The book is organised into four sections. Each section consists of a number of chapters and one or more comments on future directions in classroom research. The first two sections are headed by Graham Nuthall’s chapters and reflect the kinds of issues that concerned him. The last two sections focus on issues that figured marginally or not at all in his research. My purpose in arranging the content in this fashion is to invite the reader to engage with some ideas pertaining to classroom research that build on or respond more directly to Graham Nuthall’s research and then progressively move to issues that lie beyond the orbit of his work. Nevertheless, these later chapters also refer to some aspects of his research, attesting to the richness of his legacy.

In the first section, *Researching Classrooms, Theorising Classroom Research*, researchers from New Zealand, the USA, Brazil, Finland and the UK engage with questions of a theoretical and methodological nature about classroom research. Nuthall forcefully argued that “teachers require an explanatory theory of how different ways of managing the classroom and creating activities are related to student learning outcomes” (Nuthall, 2004, p. 277). He saw it as the task of classroom researchers to provide teachers with a framework that could help them understand this relationship. The contributors in this section showcase different ways of researching and theorising about teaching and learning in classrooms. Some of the questions that they raise are:

- Is it possible to create an integrated theory of student learning, drawing on what seem like competing metaphors of learning as acquisition and learning as participation?
- How do a teacher’s actions, planned activities and talk inter-relate with what particular students might be learning in a given context?
- What is the meaning of student learning experience and how can we, as researchers and teachers, understand these meanings?
- How are the individual and collective learnings of students co-constituted and how can these be studied?
- Given the predominantly verbal nature of classroom interaction, how can classroom talk be studied and analysed to understand teaching and learning?
- How can researchers generate enough evidence to convince policy makers, teacher trainers and teachers about the centrality of classroom talk in the quality of teaching and learning?

In the second section, *Teaching and Learning in Curriculum Areas*, too, the contributors are concerned with methodological extensions and theoretical alternatives, but the emphasis shifts somewhat towards researching teaching and learning in specific curriculum areas—science, mathematics and literacy. Some of the questions that concern authors in this section are:

- What is the nature of the learning processes taking place in students’ minds and which classroom factors directly shape these processes?
- How can teachers become aware of individual students’ processing of information (and misinformation) on an ongoing basis?
INTRODUCTION

What new insights might be generated if an individual student’s learning were analysed taking into account the influence of material and cognitive resources within situated activity of the classroom?

What counts as valued learning in specific curriculum areas such as science?

How do students learn to do science as “scientists” do, and what are the implications for their identities as learners?

What meanings do young children make of their learning experiences?

How can Nuthall’s emphasis on continuous detailed observations of individual students help to capture the depth and range of young children’s classroom experiences and understandings in specific curriculum areas, such as mathematics and reading?

How can Nuthall’s theory be used to help prospective teachers learn to focus on students’ learning instead of class management?

The third section of the book, Creating Inclusive Classrooms, concentrates on issues of diversity and equity in classrooms. Arguably the reality of increasingly diverse student populations being taught by a largely homogenous, primarily White, middle-class teacher population is one of the most critical challenges in teaching and teacher education across the Western world today (Kaur, Boyask, Quinlivan & McPhail, 2008). In addition to class, gender and culture, several other significant dimensions of diversity are encountered by teachers in classrooms, such as students with disabilities or those from Indigenous backgrounds or immigrant or refugee groups. Nuthall and his co-researcher, Adrienne Alton-Lee, quite early in their research programme identified the need to study how class, race and gender might interact with student learning by inhibiting or facilitating opportunities to learn for different students (e.g., Alton-Lee, Densem & Nuthall, 1990, 1991; Alton-Lee, Nuthall & Patrick, 1987). However, such issues were not the focus in Nuthall’s research, with the exception that learning experiences of low-achieving students did consistently feature for targeted investigation in his studies. Researchers in this section raise questions about the “taken-for-granted” assumptions in educational practices in light of the lived realities of inclusion as experienced by students constructed as different and often deficient.

What does authentic inclusion entail?

How do classroom discourses shape social and academic identities of students?

How can teachers create more appropriate, fair assessment practices and contexts to measure learning outcomes for students, who might be bilingual and bicultural, in the face of a systemic uniform testing mandate that often marginalises these students’ knowledge and experiences and constructs them as deficient?

How can culturally responsive pedagogy instead of cultural assimilation become the norm?

How can educational practice and policy become mindful of the historic wrongs and move to define “knowledge worth knowing” in ways that give equal status to the worldviews of Indigenous peoples?

Chapters in the last section, Widening Conversations In and Beyond Classrooms, open up the conversation about classroom research beyond what is traditionally
included in this field of inquiry, both by investigating the silences in what is considered worth studying within the classroom and by suggesting the significance of researching classroom practices within their historical or policy contexts. It can be argued that widening the scope of classroom research to include historical and policy contexts will blur the lines between classroom research and educational research. That position can certainly be justified. However, it is equally true that questions such as how teaching and learning in a classroom get significantly shaped by assessment policies developed at a macro level or why certain practices become prevalent (for instance, why and how the individual came to be placed at the centre of classroom learning) cannot be ignored without sacrificing a quest for deeper understandings of what goes on in classrooms (Quinlivan, Boyask & Kaur, 2009). Similarly, the overwhelming emphasis in classroom research on what students learn in terms of concepts and skills abandons any concern for the “emotional labour of learning” when the classroom norms are disturbed, and leaves little place for exploring “how teaching, as an act of courage and beauty, forms the basis for creating a spirit of community within the classroom and beyond” (Feuerverger, this volume, p. 282).

If creating a more equitable and just society is a worthy goal for education, and if classroom is not to remain an “[o]verheated, insular, stifling” place for any child, then classroom research has to widen its horizons to reflect its concern for the hitherto neglected topics of inquiry. It is hoped that this book will encourage its readers to build on Graham Nuthall’s legacy as they ponder the wide range of future research directions suggested by the researchers who bring this last section and the book to a close.

NOTES

1 For information on the Trust and a full list of Graham Nuthall’s research projects and publications, see http://www.nuthalltrust.org.nz/ For Nuthall’s own account of his intellectual journey related to the changes in classroom research trends in general, see Nuthall, 2002; Nuthall and Alton-Lee, 1990.
2 At the time of his death, Graham Nuthall had almost finished revising these two articles based on reviewer comments from two different journals. In order to share his most recent thinking with a wide readership of researchers and practitioners, it was decided to include these in the present publication. Valuable editorial advice from Professor Greta Morine-Dershimer assisted me with editing them for publication in a single volume without altering the voice.
3 For details, visit http://www.eenz.com/gncrt-sym2010/
4 The phrase, ‘In and Beyond Classrooms’, is borrowed from Johnston and Andrade.

REFERENCES

INTRODUCTION


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1. UNDERSTANDING WHAT STUDENTS LEARN

INTRODUCTION

This chapter is about how classroom activities shape the ways in which students’ minds interpret and process their experience. In previous studies we have developed a model of how students acquire conceptual knowledge and how their knowledge is changed by their classroom experiences. The model allows us to predict, from an analysis of detailed recordings of individual student experiences, exactly which concepts and principles each student will learn and remember (Nuthall, 1999b, 1999c; Nuthall & Alton-Lee, 1993). The central purpose of this chapter is to identify how the processes that lie behind the knowledge acquisition themselves are acquired and develop in students’ minds.

A second, related purpose is to clarify the way teacher actions relate to student learning through student experience. There is evidence that what teachers intend and believe to happen in their classrooms is frequently not what students experience (Cobb, Perlwitz & Underwood-Gregg, 1998; Erickson, 1996; Yair, 2000). Students’ classroom experience is shaped by many factors in addition to teacher organisation and management of classroom activities. Through a close look at individual student experience, this chapter provides an empirically based conceptual analysis of the complex inter-relations between teacher actions (together with activities that the teacher designs) and student learning.

THE SHAPING OF COGNITIVE PROCESSES THROUGH INTERNALISATION

According to Vygotsky (1978), and other sociocultural theorists (e.g., Arievitch & van der Veer, 1995; Lawrence & Valsiner, 1993), the higher mental processes (involved in learning from experience) are generated through the internalisation of culturally structured social activities. If this is true of the culturally structured social activities that make up classroom life, then what is the nature of these activities and what determines how students experience them? What sense can we make of the process of internalisation in the context of classroom activities?

Cognitive processes are not just skills that can be taught and acquired in the same way as learning to ride a bicycle or print the letters of the alphabet (Bransford, Sherwood, Vye & Reisser, 1986). Children acquire cognitive processes as part of acquiring the culture of the society in which they live, progressively, through constant guided participation in the activities and rituals that make up daily
life. Through participation, they internalise the goals and purposes, the behaviours, and the knowledge and thinking processes involved in the activities.

There is general evidence to support Vygotsky’s theory. Attending school is related to significant changes in the development of cognitive processes (Cahan & Cohen, 1989). Children of comparable age who have spent a year in school instead of kindergarten or preschool show significant advantages in a variety of memory tasks (Morrison, Smith & Dow-Ehrensberger, 1995; Varnhagen, Morrison & Everall, 1994). They use more formal and systematic memory search procedures without prompting and are better at evaluating what they know and do not know (Kreutzer, Leonard & Flavell, 1975; Sharp, Cole & Lave, 1979). Cole argues, on the basis of a series of cross-cultural studies of children’s development, that school, unlike other social institutions, requires the systematic and managed use of cognitive activities (Cole, 1996). What is unknown is how participation in school activities shapes the way the child interprets, thinks about and uses experience (Nuthall, 2000a, 2000b).

The process by which social activities become mental processes is referred to as interiorisation or internalisation (Lawrence & Valsiner, 1993; Tharp & Gallimore, 1988). According to Vygotsky, internalisation involves the progressive shifting of control of an activity from the outside material world to the internal world of the mind. Elaborating on the ideas of Vygotsky, Gal’perin suggested that internalisation proceeds through a series of stages (Haenen, 1996, 2001). Initially, an activity is carried out largely through trial and error, or under the direct control of an adult or more experienced participant. Later on, control of the activity is shifted from physical to verbal or symbolic feedback. Words or symbols used to describe and explain the activity come to stand for the activity itself. Verbal instructions, and still later self-talk, come to control the activity. In the final stage, management of the activity and its verbal representation disappear into the unconscious. The activity can be carried out mentally and the result produced without any awareness of the steps involved. It is only when the activity strikes an unexpected problem that it will re-emerge into consciousness (Vygotsky, 1981). Tharp and Gallimore have provided an abbreviated account of these “stages of the zone of proximal development” (Tharp & Gallimore, 1988, p.33). Vygotsky was careful to point out that the structure of the external activity is radically changed as it is internalised.

This sociocultural account of internalisation is not substantially different from the outline that Piaget provided in his later studies of children’s understanding and management of their physical world (Piaget, 1962, 1978). According to Piaget, as children become familiar with an activity, they experiment with variations on the activity and build up a mental image of the process of carrying out the activity and its variations. The mental image is created by a mental imitation that involves all essential aspects of imitating the activity except physically carrying it out. The mental imitation can then be used to play and replay the activity in the mind in order to try out variations and predict their outcomes internally. It is this mental imitation of the process and structure of the activity (and its variants and consequences) that becomes the process and structure of thinking and forms the
UNDERSTANDING WHAT STUDENTS LEARN

Vygotsky also sees imitation as central to the internalisation of higher mental processes (Vygotsky, 1982), but differs from Piaget in regard to the role that culture and social interaction play in the process. Most of Piaget’s experiments involved individual children interacting with, and learning to understand and manage, the natural world. Vygotsky and his followers focused on the individual being drawn into and learning to participate in social activities (cf., Rogoff, 1994, 1996). Even when the individual is interacting with the natural world the interaction is mediated by artefacts, such as language, scientific concepts and mathematical symbol systems, that embody a specific cultural history (Vygotsky, 1978, 1981). Vygotsky’s own work focused on the role of signs and symbols, especially the role of language in the development of cognitive self-management (i.e., giving instructions to one’s self). Leont’ev (1981) expanded this work by developing the concept of “activity” as the major mediator of cognitive processes. According to Leont’ev (1978), internalisation occurs because of the circular structure of an activity. “The psychic reflection of the object world is generated directly not by external forces … but by those processes through which the subject enters into practical contact with the object world.” (Leont’ev, 1978, p. 53).

If these views of the role of internalisation in cognitive development are right, then the internalisation of routine classroom activities, including the talk accompanying them, is likely to be the prime mediator in shaping and developing how students engage with classroom experience (Arievitch & van der Veer, 1995; Wells, 2002b).

ACTIVITY AS A UNIT OF ANALYSIS FOR STUDENT LEARNING

The analysis reported in this chapter is based on relatively recent developments in the concept of “activity” originating from Leont’ev. In particular, I have relied on the sociocultural theories of activity developed by Wells (1994, 1999), Wertsch (e.g., Wertsch, Minick & Arns, 1984), Engeström (e.g., Engeström & Miettinen, 1999) and Davydov (1999) to provide the unit of analysis. According to Wells, a classroom activity is a relatively self-contained, goal-oriented sequence of actions, such as carrying out an experiment, writing a story or participating in a teacher–student discussion (Wells, 1999, p. 172). As such it consists of a structured sequence of behaviours or tasks that follow a pattern intended to achieve a collective goal. The participants in an activity share beliefs about their roles, and about the behaviours and forms of cooperation that will achieve the goals of the activity. The activity gives the roles and the behaviour their meaning and significance (Van Oers, 1998). As explained below, this concept of an activity can be seen as the sociocultural version of the concept of a “script” (or schema) that has played a significant role in research on cognition (cf., Brewer & Nakamura, 1984; Derry, 1996; Minsky, 1975). Like scripts and schemas, activities are “the minimal meaningful context for understanding individual actions” (Kuutti, 1996, p. 28).
Like the enactment of a script, an activity has both general structure and unique process (Engeström & Miettinen, 1999). The *structure* describes the essential or common sequence of tasks or behaviours that are enacted whenever the activity is carried out. It also includes the commonly held (cultural) beliefs about the tasks and behaviours, the roles and status of the participants, and the cultural tools used in the activity (Engeström, 1999). However, what happens during the enactment of an activity on any one occasion is not an exact replica of its previous enactments. The *process* describes the way the activity is carried out on a particular occasion. It consists of the interactions between participants who each have their own personal characteristics, goals and past histories. Using the activity as a unit of analysis involves integrating the system or structural view with the individual or local view (Engeström & Miettinen, 1999, p. 10).

A typical classroom activity focuses on a segment of a curriculum topic such as a significant concept, understanding, principle or skill (Wells, 2002b). Several different patterns of classroom organisation might be involved. For example, a social studies activity might begin with a brief whole-class discussion in which the teacher elicits what the students already know and explains the questions the students are to investigate; it might then change to a small group research activity, and end with the students working individually on a written report. What holds the individual parts of an activity together is that they share the same intended curriculum purpose or learning outcomes.

The parts of an activity (such as a whole-class discussion, completing a worksheet, conducting an experiment) are themselves activities that have their own expected components and make a specific contribution to the larger activity. Some researchers (e.g. Wells, 2002a) focus their analysis on the smaller activities, but I consider these smaller activities as interdependent. Further, students tend to interweave elements of the smaller activities so that it is impossible to identify when one ends and the next one begins (see figure 1.3 under “The Process of Enacting Classroom Activities” below). I refer to the smaller activities as *tasks*.

The concept of activity as a unit of analysis in research on classrooms evolved within the context of sociocultural (Rogoff, 1994, 1996; Rogoff, Turkanis & Bartlett, 2001) and social historical activity theory (Wells, 2002a). Because of this background, it brings with it the claim that understanding and learning are indistinguishable aspects of participation in an activity (Barab, Hay, Barnett & Squire, 2001; Kozulin, 1995; Varelas & Pineda, 1999). “Learning through legitimate peripheral participation takes place no matter which educational form provides a context for learning or whether there is any intentional educational form at all” (Lave & Wenger, 1991, p. 40). According to Rogoff, significant learning can be defined as “transformations in people’s actual involvement in activities” (Rogoff, 1996, p. 283) and it is “unnecessary to wonder how it is that external information crosses a boundary to be stored internally” (Rogoff, 1996, p. 280). Lave argues further that the boundaries between mind and community, between thinking and social interaction, between knowing and doing are of little significance. Mind and the social and cultural world “constitute each other” (Lave, 1991, p. 63).
One of the major problems with this account of classroom learning is that it has difficulty explaining how the effects of participation in one spatio-temporal context are transferred to other contexts (Salomon, 1993). Once understanding and knowledge have developed through participation, they are assumed to have become more or less permanent possessions of the individual. According to Lave and Wenger, learning “… is the historical production, transformation, and change of persons” (Lave & Wenger, 1991, p. 51).

In earlier studies of students’ memory for their classroom experiences we have shown that not only does forgetting occur to varying degrees, but also memory processes transform knowledge and understanding in largely predictable ways (Nuthall, 2000a, 2000b). The processes of understanding, knowledge acquisition, internalisation and memory are closely linked and related to individual differences in what is learned and remembered. If the concept of an activity is to provide a useful unit of analysis for understanding the conditions under which higher mental processes are acquired, then its theoretical basis needs to be expanded to incorporate the cognitive representations of activities (scripts and schemas) that have proved useful in explaining memory processes. A brief reference to related studies on the acquisition, forgetting and reconstruction of conceptual knowledge (Nuthall, 2000a; Nuthall & Alton-Lee, 1992, 1993) will help explain my reasoning.

**ACQUISITION AND MEMORY OF CONCEPTUAL KNOWLEDGE**

In a series of studies we have established the conditions under which students acquire and remember conceptual knowledge (propositions, concepts, principles, generalisations). Predicting what conceptual knowledge students acquire involves identifying the concept-relevant information that students extract from their classroom experiences. Details of the data gathering procedures for our earlier studies were the same as those used in obtaining the data for the present study, and are described in figure 1.2 under “The Research Design and Data Analysis” below.

We found that students learned and remembered a concept if they experienced (or interacted with) at least three complete sets of the information needed to understand the concept on separate, sequentially ordered occasions. A student might interact with a complete set of information on a single occasion (e.g., a complete definition of a concept or principle) or on several separate occasions that together made up the equivalent of a full definition (e.g., parts of the definition, examples of the concept, or reasons for the principle). If a student did not encounter at least three complete sets of information, the concept was neither understood nor remembered. We were able to predict with 80–85% accuracy exactly which concepts individual students would, and would not, learn (for details see Nuthall & Alton-Lee, 1992, 1993). These procedures were subsequently validated in further studies involving data on 1,057 concepts (Nuthall, 1999c).

Close examination of the specific experiences critical to each student’s acquisition of particular concepts suggested that the learning process involved extracting information from relevant experiences and integrating and elaborating that information in long-term working memory. For example, we found that when
we compared immediate memory for conceptual learning with long-term memory, 8–12 months later, two processes were simultaneously involved: (a) progressive abstraction and loss of detail in direct recall; and (b) increasing use of inference from fragmentary recall and pre-existing knowledge structures. We also found that representations of experience in long-term memory included both semantic (conceptual knowledge) and episodic (behavioural and contextual) content (Tulving, 1993). (For similar results see McKoon, Ratcliff & Dell, 1986, and Morton, 1990.) The following example illustrates what such representations may contain.

Jan (a student in a 4th Grade class studying a unit on weather) was interviewed one year after the unit. When asked about the liquid in a thermometer, she recalled more or less exactly what the teacher and another student had said during the unit (quoted in Nuthall, 2000b, p. 101).

**Interviewer:** Where did you learn that?

Jan: Last year … Mr B said, “What’s in a thermometer?” and Troy put his hand up and said it was mercury. And it was right, and since then I have remembered.

**Interviewer:** You remember Troy saying that?

Jan: Yea.

**Interviewer:** Isn’t that amazing. What did you think at the time, did you think how clever he is or what? … Do you remember that?

Jan: I thought you have got to be wrong. I thought mercury was sort of a jewel or something like that … Or just a planet.

**Interviewer:** So you thought he was wrong?

Jan: Mm, I thought it was ink or water.

Jan’s recollection was exceptionally detailed, but illustrates the complex nature of what, at least initially, gets stored in memory. She recalled not only the episodic detail of exactly what was said and done but also the semantic content (thermometer contains mercury) and semantic processing (her thought at the time). This required her to hold side by side in memory the accepted answer, her beliefs about the answer and her own mistaken answer.

More commonly, episodic and semantic details fade and are replaced by more general or abstract recollections and details often unconsciously inferred from pre-existing knowledge structures. This process is similar in both semantic and episodic memory, so a student can recall an abstracted version of the physical context of a learning activity without recalling the semantic content or vice versa. For example, Pam (4th Grade; studying weather) “recalled” that clouds were made of “white gases”. When asked how she had learned that, she identified the teacher telling her (quoted in Nuthall, 2000b, p. 113).

Pam: Well, um Mr B [the teacher] was saying that um, the clouds are made out of white gases and when they, um, come in together they get bigger white
gases and the clouds sort of move around in different directions and sometimes maybe the white gases can just become small, or they can become medium or big or …

In fact Pam had been told about “white gases” when talking informally with peers. However, her common experience was that knowledge came from the teacher or textbook. As details of the actual learning experience faded, she inferred (and came to believe) that there must have been a learning activity in which the teacher was the source of knowledge.

Taken together, our studies of conceptual knowledge suggest that three types of processes are involved in acquiring and remembering new knowledge. First, the identification of the connection between new experience and prior knowledge involves identifying how the experience is relevant to prior knowledge and extracting the information from the experience related to specific prior knowledge. Second, the identified information is interpreted in relation to relevant prior knowledge, by using structures (schemas) in prior knowledge to infer missing information, deducing the implications of the new information for the prior knowledge and resolving any contradictions between the two. Third, as the new information is elaborated and integrated with prior knowledge structures, its most important aspects are identified and tagged as significant for retention. With this tagging, the new integrated information can be structured in ways that facilitate later recall and summaries can be created in forms suitable for such recall. Further, these processes involve both semantic and episodic information, and simultaneously involve multiple concepts and multiple sets of prior knowledge structures. Figure 1.1 represents this view of the development of conceptual knowledge.

Figure 1.1. The development of conceptual knowledge

I use structure here to refer both to the pattern and sequence of observable actions of an activity and to the internal representation of the pattern and sequence often termed a script or schema in cognitive psychology (Brewer, 2000; Brewer & Nakamura, 1984). If internalisation of the structure of classroom activities
determines the knowledge and thinking structures (schemas) that shape how students interpret and learn from their classroom activities, then what structures or patterns do typical classroom activities contain? How are classroom activities enacted and how do students experience them? What evidence is there that the structures of these activities are internalised? The key outcome of internalisation seems to be that students develop automatised self-management or control (Engeström, 1999; Hicks, 1996; Vygotsky, 1978) in view of both the teacher’s requirements and their own personal and social purposes (Winegar, 1997). By examining how students manage their participation in a typical classroom activity, it should be possible to determine what kind of model of the activity students have internalised and are using as the basis for such management.

THE RESEARCH DESIGN AND DATA ANALYSIS

The design of this study evolved from the series of earlier studies Adrienne Alton-Lee and I conducted on individual students’ experiences and learning in elementary and middle school classes (Alton-Lee & Nuthall, 1990; Nuthall, 1999b, 1999c; Nuthall & Alton-Lee, 1993). Experienced teachers who used a variety of different teaching styles were invited to participate. The project was explained to the participating teachers as an investigation into the experiences and learning of individual students in units in science, social studies and related areas, and the teachers were asked to plan and manage their teaching in the way in which they were most comfortable. The procedures used for data gathering are outlined in figure 1.2 on the following pages. Table 1.1 outlines the characteristics of the students who were the focus of this study.

The data obtained in our studies are unique for their continuous and detailed nature. Unlike most other classroom studies, there was no sampling. The continuous classroom experiences of four students and the teacher were recorded through the entire unit. This method allows for the parallel microgenetic analysis (Siegler & Crowley, 1991) of the learning experiences of four students.

<p>| Table 1.1. Characteristics of the individual students observed and interviewed |
|-----------------|---------|-------|---------|-------|---------|</p>
<table>
<thead>
<tr>
<th>Student</th>
<th>Gender</th>
<th>Age</th>
<th>Grade</th>
<th>PAT age percentile</th>
<th>Number of concept-files</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austin</td>
<td>m</td>
<td>10.9</td>
<td>5</td>
<td>79</td>
<td>47</td>
</tr>
<tr>
<td>Karin</td>
<td>f</td>
<td>10.11</td>
<td>4</td>
<td>34</td>
<td>94</td>
</tr>
<tr>
<td>Shaun</td>
<td>m</td>
<td>9.9</td>
<td>4</td>
<td>50</td>
<td>42</td>
</tr>
<tr>
<td>Sonya</td>
<td>f</td>
<td>11.1</td>
<td>5</td>
<td>33</td>
<td>19</td>
</tr>
</tbody>
</table>

a Austin and Shaun are discussed in detail in this chapter, and Sonya in chapter 6. All names are pseudonyms.
b Progressive Achievement Tests (Reid & Elley, 1991) are standardised achievement tests of reading and listening comprehension nationally standardised for use by schools in New Zealand. The reading comprehension test correlates highly with teachers’ ratings of scholastic ability ($r = 0.78–0.88$) and with standardised tests of scholastic ability ($r = 0.70–0.77$) (Reid, Jackson, Gilmore & Croft, 1981).
Figure 1.2. Procedures used to obtain data for this study
Figure 1.2. Procedures used to obtain data for this study (continued)

- The author and another observer each kept continuous written records of the behaviour of two target students. All students wore miniature broadcast microphones but only target students were recorded.
- After class each day, everything the target students (and a sample of others) read, looked at, wrote, illustrated or made was photographed.
- Over the eight days of the unit, an average of 7.4 hours’ recordings were made for each target student (one student was absent for three days).

- Each morning all students filled in a diary describing anything they had done during out-of-school hours that related to the topic.

- One week after the unit was completed, the author re-administered the test orally to the class.

- A few days after the post-test, the author interviewed each target student individually in two to three interviews of about an hour’s duration.
- Students were asked: what answer they had given to each item in the test and why; where and how they thought they had learned it; what they liked and disliked in the unit; and what they found easy or difficult to understand.

- In a further interview, the target students were shown about 15 selected excerpts from the video recordings of themselves and asked about what they were thinking and feeling at the time. The excerpts were selected to represent moments that appeared to be critical in the learning of specific concepts.

- The recordings made during the unit were transcribed, collated with observation notes and photographic records and then divided into “concept-files” – one file per student for each item in the test (see table 1.1).
- Each concept-file contained all the data for every experience that was relevant in any way to that concept along with the student’s recall of and beliefs about those experiences.
THE TASKS THAT MAKE UP A TYPICAL CLASSROOM ACTIVITY

Five of our previous studies suggested that classroom activities in science and social studies units typically consist of an ordered sequence of the following four distinct but frequently overlapping components. A similar sequence of components has been identified by Wells (2002b) and occurs in many “design experiments” (e.g., Hershkowitz & Schwarz, 1999).

a. Instructions. An activity begins when the teacher introduces the major ideas or concepts that the students are to study and provides a set of instructions about what they are expected to do and how their work will be evaluated. Such information may be conveyed through a lecture by the teacher, through a class discussion, or in printed form and/or worksheets for the whole class. Instructions are rarely fully explicit. How these are understood depends on the mutual understandings of expectations that the teacher and students have developed in similar activities previously (Amerine & Bilmes, 1988). Teachers might also include a review of previous activities and of the students’ relevant prior knowledge. Talk designed to interest and motivate the students is also likely. Students might begin the process of negotiating down the task demands (Doyle & Carter, 1984).

b. Carrying out the activity. The students engage in the experiment or research activity in pairs or small groups, on the basis of their understanding of the instructions, the explicit and implicit expectations, and their awareness of the consequences of following or not following the instructions. Students’ behaviour is constrained by the availability and usefulness of the resources and their ability to manage the social context in which they are performing the activity. It is also important for the students to understand the goal of the activity, to be motivated to achieve that goal, and to have the skills and knowledge needed to follow the instructions.

c. Preparing a report. Teachers almost always require students to record or report the outcomes of the experiment or research task, or show some evidence of their work. Because this aspect of the activity, usually completed individually, is typically the most often noticed and formally evaluated, it exerts a significant controlling influence on the way the students approach the activity (Bennett & Desforges, 1988).

d. Discussing the results. During or at the end of the activity, the teacher might discuss the activity or its outcomes with the whole class. Such discussion might relate the physical aspects of conducting the activity to the intended curriculum purposes and processes, often making connections to previous activities, prior knowledge and the implications of the outcomes. Even if the students had no idea why they were doing the activity, had interpreted its purposes quite differently from the teacher, had
not completed the activity or had obtained the wrong outcomes, this discussion would serve to tell them what they should have done, how they should have understood it and what they should have concluded (Wells, 1999).

The science unit analysed in this chapter typifies the characteristics of science and social studies activities, especially the structure described above. Students carried out an experiment on the nature of light.

**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 activity design) and management of student behaviour. However, as the following analysis will show, student behaviour and experience are a function of the students’ simultaneous involvement in three different sociocultural contexts. First is the visible public context of the classroom activities that the teacher designs, organises and manages both directly in face-to-face interaction with the students and indirectly through the design and organisation of individual and group tasks. This context is usually, but not always or completely, bounded by the classroom. Second is the semi-private context of peer relationships and interactions operating within the peer culture largely invisible to the teacher (Benenson, Apostoleris & Parnass, 1998; Ladd, 1999; Wentzel, 1999). Beyond the classroom this context includes the playground and out-of-school areas where students interact. Third is the private, internal context of the student’s own cognitive and emotional processes that bring past experiences and motivations to bear on the student’s perceptions and involvement in current activities (Alton-Lee, Nuthall & Patrick, 1993). This context exists whenever and wherever the student thinks, talks or reads about the relevant content (e.g., in the classroom, in peer interactions or in bed at night).

These contexts are “sociocultural” because their content has its origins in social interaction within culturally structured contexts. Each operates as a system with its own history, expectations, rules, procedures, outcomes and physical locations. Although these sociocultural contexts interact with each other within the classroom, they are structured differently, involve different processes and affect learning in different ways (Nuthall, 2001). Cazden, who identifies two contexts (the public and the peer culture), describes them as “interpenetrating worlds” (Cazden, 1986). To Cobb and his colleagues, the two contexts they identify (the public and the personal) are “reflexively” inter-related (Cobb et al., 1998).

How the Teacher Framed a Science Activity in a Grade 4/5 Classroom

To illustrate the structured sequence and processes that make up a science activity, the experience and behaviour of two target students working in different groups (Shaun and Austin) have been analysed.

The purpose of the activity was to observe and explain the magnifying effect of looking through a drop of water. It was one of a set of three experiments related to “magnifying things”. The instructions (printed on a card) asked the students to
place drops of water on a thin film of transparent plastic (trade-name Gladwrap) stretched over a printed page, to look through the drops, record what they saw, and decide whether larger drops magnified the print more or less than smaller drops. This “water-drop” activity followed the typical sequential structure of the four components described above.

Giving instructions. At the beginning of the “magnifying things” activities, the teacher gave the students a printed instruction card that also listed questions to focus the students’ observations and thinking (e.g., “What happens to light when it goes through water? Do large drops of water magnify print more than small drops?”). After handing out the instruction cards the teacher talked to the whole class about the requirements for materials and report writing. 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 this activity instead of giving this list, she reminded the students of the headings.

In addition to the printed instructions and the class discussion, there were implicit expectations about how the students should behave. The students knew that they would be working in groups with specific roles (e.g., one student responsible for resources), the report should be written in their “topic” book, the teacher would read and evaluate their written reports, the teacher expected them to work together, focused on the task, without getting distracted, and so on. As the subsequent analysis shows, the teacher continued to amplify these instructions and remind students of expectations during her frequent interactions with each group.

Discussing the results. Once the groups had carried out the experiment (about 40 minutes later) the teacher began a whole-class discussion.

Teacher: Okay… 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 too. 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 …

Teacher: Got any ideas why that was, Bettina?

Bettina: ‘Cause it was rounder.

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 instructions and this final discussion created a frame within which the students carried out the “water drop” experiment. The beginning discussion reiterated the requirements the students were familiar with, and added the specific requirements of this activity. The final discussion informed and/or reminded the students of what they had done and the “scientific” explanation that was the major outcome of the activity.

How the Students Enacted the Activity

To summarise how each group carried out the sequence of tasks that made up the water drop experiment, a category system was developed for the students’ behaviours. 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 (peer interaction unrelated to task procedures, spending time doing nothing active) were added to make the category system fully inclusive.

Within these categories, student behaviours were further divided into those done individually, interactively with peers, and with the teacher’s support (see the Appendix).

The percentage of time the students spent engaged in each of these behaviours is reported in table 1.2. On average, the students spent about a quarter of the time (24.1%) getting specific instructions, interpreting the instructions and gathering the required resources. Nearly 40% of the time was spent carrying out the experiment and observing and discussing the results, and about a third of the time (32.5%) was spent organising and writing the report.
Table 1.2. The percentage of time students spent engaged in different behaviours during experimental and report writing phases of the science activity

<table>
<thead>
<tr>
<th>Type of behaviour</th>
<th>Shaun</th>
<th>Austin</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Getting and clarifying instructions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher instructions to whole class</td>
<td>10.6</td>
<td>9.1</td>
</tr>
<tr>
<td>Teacher instructions to group</td>
<td>2.4</td>
<td>1.2</td>
</tr>
<tr>
<td>Individually reading instructions</td>
<td>1.8</td>
<td>1.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>14.7</strong></td>
<td><strong>11.5</strong></td>
</tr>
<tr>
<td>B. Interpreting instructions and getting resources</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interactively with peers</td>
<td>8.2</td>
<td>3.0</td>
</tr>
<tr>
<td>Interactively with teacher</td>
<td>0.6</td>
<td>2.4</td>
</tr>
<tr>
<td>Individually getting resources</td>
<td>1.2</td>
<td>3.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10.0</strong></td>
<td><strong>8.5</strong></td>
</tr>
<tr>
<td>C. Carrying out required task procedures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carrying out procedures individually and interactively</td>
<td>4.1</td>
<td>5.5</td>
</tr>
<tr>
<td>Talking with group about results and reasons</td>
<td>6.5</td>
<td>4.2</td>
</tr>
<tr>
<td>Talking with teacher about procedures, results and reasons</td>
<td>10.0</td>
<td>14.5</td>
</tr>
<tr>
<td>Carrying out incorrect procedure and accidents</td>
<td>1.8</td>
<td>1.8</td>
</tr>
<tr>
<td>Engaged in alternative or playful activities</td>
<td>15.3</td>
<td>12.7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>37.6</strong></td>
<td><strong>38.8</strong></td>
</tr>
<tr>
<td>D. Peer interaction unrelated to task procedures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organising materials and finding out what to do, individually or interactively</td>
<td>10.0</td>
<td>4.2</td>
</tr>
<tr>
<td>Talking about content of report with teacher</td>
<td>7.1</td>
<td>3.0</td>
</tr>
<tr>
<td>Writing and illustrating the report</td>
<td>10.6</td>
<td>26.7</td>
</tr>
<tr>
<td>Reading own and other students’ writing</td>
<td>5.3</td>
<td>6.7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>32.9</strong></td>
<td><strong>40.6</strong></td>
</tr>
<tr>
<td>E. Writing the report</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organising materials and finding out what to do,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>individually or interactively</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Talking about content of report with teacher</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Writing and illustrating the report</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reading own and other students’ writing</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>32.9</strong></td>
<td><strong>40.6</strong></td>
</tr>
<tr>
<td>F. Spending time gazing around, doing nothing</td>
<td>2.9</td>
<td>–</td>
</tr>
<tr>
<td><strong>Total number of 15-second intervals</strong></td>
<td>170</td>
<td>165</td>
</tr>
</tbody>
</table>

Table 1.3 presents the data re-organised according to whether the student was working individually, interactively with other students or with the teacher. On average, the students spent about 30% of their time interacting with or listening to the teacher, and nearly the same amount of time interacting with or listening to their peers. However, more than a quarter (28%) of the peer interaction time was unrelated to the intended tasks. For about a third of the total time the students engaged in individual behaviours directly related to the intended activity (e.g., writing the report), and for the remaining 10% of the time they were engaged in individual behaviours not directly related to the experiment (e.g., using a 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 in monitoring and guiding students’ activity as well as the complexity of the task and students’ lack of prior knowledge directly relevant to it.
Table 1.3. The percentage of time students spent working individually, interacting with peers or interacting with the teacher during the experimental and report writing phases of the science activity

<table>
<thead>
<tr>
<th>Social context</th>
<th>Shaun</th>
<th>Austin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interacting with the teacher</td>
<td>28.2</td>
<td>29.1</td>
</tr>
<tr>
<td>Interacting with peers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Related to intended activity</td>
<td>24.7</td>
<td>15.2</td>
</tr>
<tr>
<td>Unrelated to intended activity</td>
<td>10.6</td>
<td>4.9</td>
</tr>
<tr>
<td>Individual activity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Related to intended activity</td>
<td>27.1</td>
<td>42.4</td>
</tr>
<tr>
<td>Unrelated to intended activity</td>
<td>9.4</td>
<td>8.5</td>
</tr>
</tbody>
</table>

Interpreting Instructions and the Sequence of Major Events

The sequence of each group’s attempts to carry out the water drop experiment and the teacher’s interventions is summarised in table 1.4.

Both groups started the experiment on their own but, because of their difficulties, both carried out the experiment two or three times, initially with partial teacher help and finally with close teacher guidance.

Table 1.4. The sequence of occasions the two groups carried out the “drop” experiment during the science activity

<table>
<thead>
<tr>
<th>Shaun’s group</th>
<th>Austin’s group</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Group attempts experiment on its own</td>
<td>1. Group attempts experiment on its own</td>
</tr>
<tr>
<td>Intervals$^a$ 29–35</td>
<td>Intervals$^a$ 32–42</td>
</tr>
<tr>
<td>2. Teacher starts the group on repeating experiment; the group completes it on its own</td>
<td>2. Group attempts to do the experiment again on its own</td>
</tr>
<tr>
<td>Intervals$^a$ 36–41</td>
<td>Intervals$^a$ 99–103</td>
</tr>
<tr>
<td>3. Teacher questions group about results and does the experiment with the group</td>
<td>3. Teacher questions group about results and does the experiment with the group</td>
</tr>
<tr>
<td>Intervals$^a$ 98–109</td>
<td>Intervals$^a$ 126–133</td>
</tr>
</tbody>
</table>

$^a$The time intervals identified are 15-second intervals numbered in sequence from the time the students began carrying out the experimental phase of the science activity.

1. The sequence of events in Shaun’s group. In Shaun’s group, Maurice organised the experiment and did most of the work himself. All except Maurice mistakenly thought that the purpose of the experiment was to look at a drop of water through a magnifying glass, possibly because they had been using magnifying glasses in previous activities. 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 at the drop through a magnifying glass): And more clearer.

Shaun (also looking through a magnifying glass): And shiny.

Maurice then organised the group to put more drops on the page and 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 again 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 students: Bigger.

The teacher suggested they put another, bigger drop on the page and 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”.

At this point the teacher warned the whole class to be careful with their observations. Shaun’s group did not respond to this direction and it was not until the end of the class time that the teacher found out they still thought the big drop magnified more. She then made the group do the experiment again, 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 the right result, the teacher asked them to think about why the little drop magnified more, and moved on to the next group.

It is evident that the group was confused about what they should be looking for, and produced several different answers (clearer, shiny, humungous, colour-fuller, normal). They were also confused by their belief, based on previous activities, that they should be using a magnifying glass. Although Maurice was normally credited by others in his group with knowing more, the confusion about what they should be looking for subverted his attempts to manage the activity.

2. The sequence of events in Austin’s group. Similarly when Austin’s group carried out the experiment and looked through the first drop of water on the plastic sheet, they could not agree about what they saw.
Austin: It doesn’t look any different.
Rowena: It does so! Look. It’s 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 spilling the water and did not complete the experiment. Later, after they heard the teacher telling the class to be careful with their observations, two of the girls in the group repeated the experiment while the others watched. They carried it out quickly (because they had already started to write their reports) and announced the results to the others (“So the big one makes it look bigger than what the little drop does”).

Several minutes later the teacher joined the group and when she saw they had made a mistake, she helped them carry out the experiment again, telling them exactly what to do.

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 group, this group made several attempts to carry out the experiment and it was not until the teacher intervened and conducted it with the students that they knew what they were supposed to do and observe. The teacher stayed with this group as they began to discuss the reasons for their results, helping them think about relevant evidence.

The Sequence of Behaviours for Each Target Student

Another way of describing how the students carried out the activity is to show the sequence of behaviours using the categories listed in the Appendix. Figure 1.3 shows the sequence of behaviours for two target students during the times they were conducting the experiment and writing their reports.
Figure 1.3. The sequence of activities in Shaun’s group and Austin’s group

Note: Shaded segments in each column represent engagement (see the Appendix for full definitions): Column A = getting and clarifying instructions; Column B = interpreting instructions and organising resources; Column C = carrying out the procedures; Column E = writing the report; Column OT = engaging in off-task behaviours. The numbers down the side of each column represent 15-second intervals numbered since the activity began.
The most important aspect of figure 1.3 is the extent to which the different tasks overlap with each other. Students did not follow the logical sequence of instructions by completing the experiment before writing the report. Instead, they engaged in getting and clarifying additional instructions at intervals almost throughout the activity. They started the experiment early and went back to it several times. Moreover, because the report signalled the end of the activity and was the basis on which the teacher evaluated them, the students began to write it almost as soon as they had any idea of what it was supposed to contain—before they had finished clarifying instructions or carrying out the experiment.

HOW THE THREE CONTEXTUAL SYSTEMS INFLUENCES STUDENTS’ ENACTMENTS

This analysis of how the students carried out the experiment indicates that, despite constant monitoring and intervention by the teacher, students varied considerably in what they did and understood about the activity tasks. To understand these individual differences it is necessary to analyse how the students’ behaviours were shaped by their participation in the three different sociocultural contexts: the public instruction–evaluation system; the semi-private peer relationship system; and their own individual knowledge and belief system.

1. The Public Instruction–Evaluation System

Although each group had printed instructions, these could not be detailed enough to guide their behaviour with the precision needed to make the experiment work. The teacher moved from group to group monitoring the way the students followed the instructions, initially intervening briefly to correct or assist their activity. As she noticed the students’ confusions, she spent more time with each group amplifying and modelling (Day, Cordon & Kerwin, 1989) the procedures by providing additional details, clarifying their misconceptions, reminding students of their previous knowledge, guiding their focus for observations, reiterating that proof is important in scientific inquiry and helping them to develop explanations for their observations. Taken together, the teacher’s prompting and cueing guided the students towards her conception of the structure of a scientific experiment. This consisted of both a set of procedures (e.g., focused and accurate observing) and ways of thinking about the procedures and results (relating them to previous experiences, proving and explaining the results). Between them, the teacher and the students in each group mutually constructed a unique and partial version of the procedures and discourse of this teacher’s conception of science (Varelas, Luster & Wenzel, 1999).

2. The Peer Culture Interaction System

How the students actually experienced and understood the activity was also determined by the relationships that were evolving between them within the peer
culture. Although the teacher had specified general roles for each student, their expected roles and status within the peer culture determined which students carried out which aspects of the procedures, how decisions were arrived at, whose observations were considered correct, and who determined and announced the results (Bianchini, 1997; Holland, Anderson & Palincsar, 1994; Solomon, 2000; Yerrick, 1999).

The two groups operated in different ways. In Shaun’s group, one well-informed student (Maurice) took on the role (with the others’ consent) of organising and informing everyone about what needed to be done, regardless of the roles the teacher had specified.

Maurice (reading from instruction sheet): What does this say? Stick your finger in the small jar and 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 experiment. He was the one who announced what the group 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 despite several attempts by Maurice to help him. As a result, there were several occasions when Maurice separated himself from the group to complete the task to his own satisfaction.

In both groups, influences on the approach to the experiment were: the relationships between the students; the match or mismatch between their respective roles and status; their abilities to negotiate help or cooperation; and the tensions between their need to work together within the group and their need to sustain their relationships with others outside the group (Roth, McGinn, Wosczyna & Boutonné, 1999; Sage & Kindermann, 1999).

3. The Student’s Own Knowledge and Belief System

Each of the students brought to the activity different motivations, interests, knowledge and skills. Shaun was concerned to understand what the experiment
was about but he was even more concerned with getting his report correct. Once he started to write his report, it became the focus of his attention to the extent that he failed to hear the teacher’s explanations. Assuming 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 water drop experiment was to look at drops of water through a magnifying glass. Each time his group carried out the experiment, Shaun looked at the drops through his magnifying glass. As a consequence, he wrote in his report that the reason for the result was that “it was magnified” and remembering Maurice’s earlier comment, he added “… and water makes light go slower”.

When Shaun saw the difference between his own report and Maurice’s, he decided he had made a critical mistake. He became upset and started crying quietly to himself. Despite the teacher (and Maurice) assuring him that the mistake was not important (“Don’t worry about it … It’s not worth worrying about Shaun, okay?”), he stopped participating in the group and did not see what happened when the teacher helped the group do the experiment again.

When he was interviewed two weeks later, Shaun still misunderstood the activity. He connected using a magnifying glass directly to the drop experiment.

Interviewer: Did you use one [a magnifying glass] in class?
Shaun: Yeah. We did. 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 this effect, he was unable to do so.

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 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.

Shaun: Well, when it hits, when the light and, when the light hits the um, the water, it makes bends that are in there …

Interviewer (later in the interview): … when light goes through water. Does that make it go slower … or does it actually go faster through water?
Shaun: It goes slower because when like the sun hits something shiny and that, it makes it slow down.

Shaun’s failure to understand the experiment or what he was supposed to write meant that despite his initial interest in the topic (and in experimenting with a
magnifying glass) he found the experience upsetting and withdrew from any attempt to make sense of the activity.

Austin played a more active role in his group. He started the activity with more relevant background knowledge and frequently contributed to the group’s discussions.

Teacher (talking to group): What happens to light when it goes through water?

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.

However, when Austin was writing his report and got to the point of explaining the effect (“Why I think this happened”) he was puzzled by the group’s result and did the experiment again by himself. Austin was confident in his own observations and knowledge, despite what others said and did, and independently constructed his own explanation. He 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.”

Austin was developing his own understanding of a scientific explanation. When his group was asked to provide an explanation for rainbows, Austin spent time looking through books for clues to the explanation. He did not quite know what he wanted but he knew that the others in his group had the wrong kind of explanation.

Derek: What are you looking for?

Austin: What causes a rainbow.

Derek: What causes a rainbow?

Austin: It’s the reflection of raindrops or something or light.

Derek: Austin, when it rains the rain comes down and causes the rainbow. It does.

Austin: Yeah it does. But scientifically, okay.

Derek: The sun throws light into …

Austin: Scientifically. Not just the sun comes out after it rains.

Derek: A rainbow. You see colours out of longer raindrops.

Austin: Yeah but scientifically, okay. Stop for a minute.
(Austin turns in his seat and waves for Mary to come back to the table.)

Mary: I already know.

Derek: He wants to know scientifically.

Like Maurice, it was important for Austin to understand the purpose of the activities and to make what he thought of as “scientific” sense of the results. This personal agenda transformed the way he participated in the activity and the way he managed his interactions with others and with the materials.

The personal goals, understandings, background knowledge and motivations differed for each student and resulted in significant differences in what they did and what they learned from the activity. Although the students were supposed to carry out the experiment as a group, some students like Austin and Maurice worked individually when they felt the group was not focused or operating the way they wanted. Perhaps the best way to summarise the differences between the students in what they learned from the activity is to compare their written reports:

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

Shaun: It happened because it was magnified and water makes light go slower.

During the interview it became clear that Shaun did not understand the second part of his answer, confusing refraction with reflection. Austin’s explanation is an amplification of a discussion his group had with the teacher. It was clear during the interview that he had a valid but limited understanding of his explanation.

PERSONAL MODELS OF THE CLASSROOM ACTIVITY

To identify the different structures underlying the individual versions of a science activity, the characteristic pattern of behaviour of the selected students was analysed for the seven different science activities in the unit. In the interest of brevity, only one student’s model (Austin’s) is presented here. Because internalisation appears to be a function of the way the students manage their participation (Hicks, 1996) and negotiate their role in the activity (Winegar, 1997), the focus of this analysis was on the decisions that the student made when he encountered difficulties or needed to take the initiative in carrying out the activity.

Austin’s Model of a Science Activity

The analysis identified the following components in Austin’s model of the experiment.

– Deciding what needs to be done. Austin was less concerned with the details of an activity than with its purpose. He usually interpreted the purpose as finding out about how things worked (a reversed reflection, a magnified image).
Carrying out the instructions. Once Austin had identified the kind of result the experiment was intended to produce, he took the lead in conducting the experiment and varying the procedures to get better observations. He experimented with the equipment to see if it could produce different effects. He checked others’ results and tried to correct them if he thought they were wrong.

Deciding what to write in the report. Writing the report was a lower priority for Austin. His reports were frequently incomplete and his diagrams were not a good representation of what he had observed and discussed with other students. Austin saw it as important to use his own words and rarely compared his work with others’. When he did not understand what he heard or read, he would repeat it to himself several times or ask the teacher, but rarely ask for help from other students (see table 1.3).

Criteria for judging the activity. Observing the effect of the experiment and understanding the reasons for it were Austin’s primary concerns. He also tried to describe and explain in his own words as though that approach would keep his learning consistent with his prior beliefs. Getting the activity right was more important than getting it finished on time.

Maintaining peer relationships. Austin was confident in his own knowledge and was prepared to debate a difference with other students. He was confident of his ability to help other students and happy to do so. He chatted informally to others but without any dominant interest in maintaining relationships with his friends and peers.

Dealing with difficulties. When confronted with difficulties, Austin would try to work them out for himself. He would read and re-read the instructions, repeat the experiment with variations and/or draw on his previous knowledge. This pattern of behaviour is illustrated in the following excerpt from the video-cued interview, with the focus on the task of drawing the way a picture was reflected in the shiny surface of a curved bowl.

Interviewer: Can you remember what you were seeing here in the bowl?
Austin: I wasn’t seeing anything ’cause it was like all blurry.
Interviewer: Was it all blurry?
Austin: Like ’cause I wasn’t holding the bowl … You had to put the, um, picture flat on the ground and the bowl sitting on it so that you could see the picture in the side of it. I was like, holding it up and trying it on the inside of it, so didn’t get any picture.
Interviewer: Right. What does it feel like when you try something like that and it isn’t working?
Austin: Doesn’t worry me.
Interviewer: You don’t mind? …
Austin: Well, I knew that if you had a mirror and you got a reflection it would look all big and tall. So yeah, I already knew that …
Interviewer: Do you know why it’s like that?
Austin: Um, 'cause if it curves out you get a bigger picture. It makes it all wider.

In summary, Austin believed the main purpose of the activities was finding out about natural phenomena and understanding the reasons for them. In this sense, he understood the essential difference between a science activity and other class activities. This understanding provided the basis on which he connected the results of the science activities to his out-of-school interactions with the physical world, and was increasingly interested in working out explanations. He was developing a basic understanding of a scientific explanation as something that involved underlying technical processes.

His conception of the purpose and nature of the activities was reflected in what he recalled about the activities several weeks later. Austin had an excellent memory for the details of what he observed and what he understood about the reasons for his observations. For example, when he was asked how he had learned that white light is made up of the colours of the rainbow, he recalled what he saw when he looked through a prism. Looking through a prism was not a required task, but one he set himself when he was trying to understand how a prism worked.

Interviewer: How did you know that white light was made up of many different colours?

Austin: 'Cause like, with the prism. It like, splits the light.

Interviewer: It splits the light?

Austin: Yeah.

Interviewer: So how would you have first learned about that do you think?

Austin: Um, 'cause we, um, when I looked, put the prism up against my eye and looked at the windows and it was all colour, all different colours … They came out of the prism. Yeah. The white light.

All video-cued interviews, when the students were shown video-clips of themselves carrying out the tasks, began with an open-ended question: “What is going on here?” Austin described the semantic (curriculum) content of the task in 45% of his responses (Nuthall, 1999a). This tendency suggests that the classroom activity schemas that were developing in his mind were shaping (as schemas do) his perceptions, understandings, behaviours, relationships and memories (Derry, 1996).

DISCUSSION AND CONCLUSIONS

Two different kinds of conceptual learning occur simultaneously and interactively in the classroom: the learning of the curriculum content—the knowledge, beliefs, concepts, skills and attitudes that make up the intended outcomes of specific learning activities; and 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 students’ minds perceive, interpret, process and
remember experience. Piaget describes these structures and processes as intelligence. Vygotsky and Leont’ev describe them as the higher mental processes.

As students acquire curriculum content, their cognitive processes are being shaped both by the curriculum content (its structures and inter-relationships) and by the structure of the activities in which they encounter that content. Exactly how this latter type of learning (or internalisation) occurs can only be inferred from a close analysis of the actual experiences of individual students. We know that students learn and remember different things from engaging in what appear to be the same activities. It is easy to assume that these differences are the function of the inherent abilities that students bring to the classroom. But there is significant evidence that classroom experience can shape student ability (Cole, 1996; Nuthall, 1999b; Oakes, Wells, Jones & Datnow, 1997) and well-developed theoretical analyses of how this shaping might occur through the internalisation of structures inherent in experiences (Arievitch & van der Veer, 1995; Lightfoot & Cox, 1997; Piaget, 1978; Vygotsky, 1978, 1981). What we do not understand is how this internalisation actually occurs in the context of classroom activities.

What Kind of Model of the Activity Was Internalised?

It is evident that the interaction of the factors described above resulted in considerable individual variation in how students enacted and experienced the activity. For Shaun, the activity made personal sense. He connected the content to his previous experience, but misunderstood the purpose of the task (he thought it involved using a magnifying glass), and connected the content to the wrong kind of experience (he connected refraction to his experiences of light reflecting off water). As a consequence, he found the activity distressing and made use of a more knowledgeable peer to tell him what he should be seeing and reporting. In the model of an activity evolving in his mind, the purpose remained a mystery (known to others but not himself) and the procedures seemed arbitrary. He probably had little confidence in his own knowledge and ability in science and little understanding of the ordered sequence that constituted a science activity.

Austin, on the other hand, was primarily interested in the observations he made during the activity. He saw it as a way he could find out something more about the world. Because he made direct connections with relevant previous experiences, he had a better sense of what the experiment was about and how his observations could be “scientifically” explained. The model that was evolving in his mind was structured partly by the teacher’s requirements and partly by his own independent interactions with the physical world. He knew he could depend on his own previous experience even when the teacher and his peers disagreed with him. He expected the activity to make sense in his own terms, which did not include report writing.

This analysis suggests that, if Piaget’s and Vygotsky’s theories of the development of higher mental processes are correct, students like Austin come to process and learn from classroom experience in a different way from students like Shaun. Austin was internalising a functional structure for investigating and making
sense of the world. Shaun was internalising socially functional structures, acquired and used to facilitate his interactions with teacher and peers as sources of information about how to complete an activity successfully.

It should not be assumed from the wide variation and fragmentation in the ways the students experienced the activity that this was an inadequate teacher using inappropriate materials. The teacher was experienced and rated highly by the school. The instructions the students read and followed during the activity were part of a commercially available science unit that had been produced and trialled by a group of experienced science teachers. It contained an effective teachers’ manual, which this teacher used. A casual observer would have seen a well-run classroom in which the students (from a lower-middle-class neighbourhood) appeared to be interested and wholly engaged in group and individual activities. The teacher had excellent rapport with the students and constantly monitored their behaviour and progress. There is no reason to believe that the variability and fragmentation in student experience, understanding and learning, as identified in this chapter, would not be found in any well-run classroom when continuous detailed recordings of individual student experience are used as the basis for analysis (for other examples, see Alton-Lee et al., 1993).

*What is the Evidence for Internalisation of the Structure of Classroom Activities?*

As noted at the outset, three types of cognitive processes are implicated in the acquisition and retention of conceptual knowledge (see figure 1.1). These processes occur automatically and unconsciously, guided by those cognitive structures (scripts) that determine how the processes operate in long-term working memory. If these structures are acquired through the internalisation of the structures of classroom activities, then there ought to be some discernible relationship between the patterns in classroom activities and the cognitive structures that determine how students manage and learn from these activities.

A comparison of the structures of the classroom activity experienced by the individual students (see “Personal Models of the Classroom Activity” above) and the cognitive structures identified as critical to the acquisition and storage of conceptual knowledge (see figure 1.1) suggests that the cognitive structures are components of the larger classroom activity structures. For example, the first type of cognitive structure (identification of the connection between new experience and prior knowledge, etc.) involves subconsciously asking and identifying answers to questions like: “What is this about? What kind of thing is this? What do I know that is like this? Is this an X? What does this say (let me know)?” Such questions need to be asked and answered continuously throughout the activity so that the experiences generated by the activity make sense and connect to each other in meaningful ways. This need suggests that the role of classroom activity structures is to determine which of these cognitive processes is brought into play, with which focus, in which contexts, and in which order.

It seems likely that the processes sketched in figure 1.1 are acquired from a wide range of structured experiences in a variety of classroom activities. But what is the
evidence that the structure of a classroom activity was internalised as a cognitive structure?

As already noted, the key to the successful internalisation of cognitive structures and processes is the ability to effectively control or manage participation in an activity (Engeström, 1999; Vygotsky, 1978). To what extent, and in what ways, could the students in this study be said to have effectively managed their participation in the science activity? The analysis of the characteristic ways in which Austin and Shaun made decisions about their participation suggests that students manage their participation in uniquely individual ways that depend on their personal motivations and prior knowledge. What seems to matter most are the individual goals and interests the students bring to the activity. These determine the criteria the students use to evaluate what counts as the activity, what is most significant in the activity, when the activity has been successfully completed, and what is perceived, puzzled over and thought about.

Closely related to individual goals and interests is the student’s prior knowledge and experience and initial understanding of the activity. Shaun initially saw the activity as an opportunity to find out more about the world, especially in terms of what you could do with a magnifying glass. As a result of his misunderstanding of what the activity involved and his connecting it to inappropriate background knowledge, he came to see the sole purpose of the activity as finding out what he needed to write in his report.

Because students’ interests and motivations vary from time to time and from context to context, there can be no certainty that the continuity built into the curriculum will be experienced as continuity by the students. Assuming that it is the repetitiveness of activity structures that leads students to internalise them, it is difficult to know how often and in what ways students perceive and experience classroom activities as being the same.

The Expansion of Sociocultural Theory

The highly individualised and fragmented nature of students’ involvement in classroom activities raises questions about the theoretical and practical adequacy of the sociocultural analysis of learning in the classroom. My position is that the standard sociocultural theory, as described by Engeström, Lave, Rogoff, Wells and others, needs to be augmented by the addition of cognitive information-processing concepts—such as the concepts of a schema (Brewer, 2000) and a long-term working memory (Ericsson & Kintsch, 1995; Nuthall, 1999b)—in order to account for the distinctive, as well as interactive, roles played by individual understanding, knowledge, memory and motivation.

The major issue at the centre of sociocultural theory is the relationship between social interaction and internal cognitive processes (Shotter, 1993). It is claimed that to treat the social and the cognitive as different is to misrepresent reality through a false dualism: “We treat conceptual understanding as a part of activity and not as structures in the mind” (Barab et al., 2001, p. 52). Learning occurs as new knowledge is mutually created through participation in the discourse and activities.
of the classroom. The great advantage of this theoretical approach is that it has inspired and justified the detailed examination of classroom discourse and the social interaction between teachers and students in whole-class and small-group contexts. It has reinforced the view that classroom learning can only be explained by careful attention to individual student experiences and their context.

But trying to avoid locating learning in the head of the learner has led to a failure to take account of individual differences in the ways students understand and interpret their experiences (see Wells, 2002a, as an exception). Sociocultural theorists seem to have lost sight of the fact that when students and teachers interact they mutually construct not knowledge (which implies understanding, believing and remembering) but experiences and information that can, potentially, be understood and remembered, depending on how they individually interpret and process the experiences and information.

The sociocultural view of learning has also been described as an “apprenticeship” in which the student gradually becomes, under guidance from more experienced or expert members, a full participant in a community of practice (Rogoff, 1994, 1996). The evidence reported in this study makes it difficult to understand in what sense a science class (or the groups in which the students worked) could be described as established “communities of learners” into which the students were progressively initiated. Neither the class nor the groups developed an established culture (with specified roles and status mutually known and understood by a core of experts) during the science unit. Only the teacher had such expertise, and she was only able to impart that expertise in brief visits to each group. Each group consisted of students who were all equally naïve about the teacher’s model of the activity. Some students had high levels of relevant background knowledge but all actively created ways of pursuing their own goals within the context of the teacher’s attempts to engage them in her model of the activity.

Although this study has identified a variety of different determinants of student classroom experience and behaviour, more research is needed to understand the part they play. For example, unresolved in this analysis is the function of the larger societal culture—specifically the way cultural stereotypes and beliefs about gender, class, and ethnic status and roles—shape student beliefs and participation. In our previous studies we found that the effects of cultural stereotypes and beliefs emerged most powerfully within the peer culture (cf., Alton-Lee, Densem & Nuthall, 1991; Alton-Lee, Nuthall & Patrick, 1987). Even in classrooms where the teacher is actively promoting inclusive activities, the underground peer culture may continue to operate in divisive and destructive ways (Alton-Lee et al., 1993).

If the analysis presented in this chapter has some validity, then it implies that teachers could benefit from seeing what they do in the classroom through the lens of activity theory. Their focus needs to shift from assuming that activities are merely the vehicle through which curriculum content is acquired to seeing the ordered sequence of tasks that make up an activity as a major determinant of how students understand and learn from their experiences—that is, as the source of their learning capacity or “higher mental processes”.
UNDERSTANDING WHAT STUDENTS LEARN

But this suggestion assumes that the teacher is able to create continuity of experience for the students. The major problem is that a teacher cannot be aware of exactly how individual students are participating in and understanding the classroom activities. All the teachers can do is monitor the behaviour of a sample of students on a sample of occasions, with, perhaps, additional attention to those individuals they predict to be most likely to misunderstand or deviate from expectations (Leach & Scott, 2000). If they are to internalise effectively, students need to engage intelligently and flexibly in the appropriate sequence of tasks on a number of different occasions in varying contexts. If an appropriate activity schema is to become established in a student’s working memory, then repeated experience of the essential components of the activity is mandatory.

This requirement means, first, that teachers need to ensure that the students understand and accept as personally meaningful the learning goals of an activity. Achieving these conditions is not just a matter of clarifying goals and exciting interest in them, but of ensuring the students have the knowledge to understand and appreciate the significance of those goals to them personally. It is only through understanding the purpose and role of the appropriate cognitive skills that the student will learn to manage their application in ways that are consistent and lead to internalisation.

Second, it means that teachers must work hard to establish patterns of component task behaviour as automatic working routines. The notions of internalisation and scaffolding (Collins, Brown & Newman, 1989) imply that in the early stages of instruction, behaviour patterns need to be controlled by external feedback and rewards. More formal instructional procedures are required until students come to understand the significance and practical value of the task behaviours. External management must be withdrawn when no longer needed. However, it is extraordinarily difficult, but necessary, for a teacher to know how and when individual students can be left to manage their participation without external structure or guidance.

Much has been written about the design of classroom activities that is consistent with this view, specifically work on the design of intellectually stimulating (cf., Anderson et al., 2001) and conceptually rich (Barab et al., 2001) group activities. What my study implies is that teachers, in addition to working on the students’ motivations, need to design and manage activities so that they require all students to engage in the set of cognitive processes that produce an elaborated, coherent and reasoned network of knowledge and beliefs. They need to constantly assess, monitor and scaffold student understanding and involvement in those activities as well as be aware of how students manage their concurrent participation with each other within the peer culture. Critical to the ways students understand, experience and participate in activities are the quality of student relationships, the ways they value the participation of their classmates, the roles and status that develop within those relationships, and the culture and values they cultivate (Kollar, Anderson & Palincsar, 1994). In other words, the culture of personal relationships between students, because it plays a critical role in determining how students participate in classroom activities, must be seen as shaping the kinds of cognitive processes that
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students internalise (Yerrick, 1999). At the heart of this chapter has been the concern to develop understanding of how teaching, learning and cognitive development are inter-related by translating the widely discussed theories of intellectual development of Vygotsky and Piaget into the realities of the classroom.

EDITOR’S NOTE

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NOTES

1 The term concept has been used as a general term to refer to all the different kinds of propositions, understandings, principles and generalisations that are the standard knowledge outcomes in science, social studies and other knowledge-focused curriculum areas.

2 See note 1.

3 This is a revised version of the cognitive processes described in earlier reports (Nuthall, 1999a; Nuthall & Alton-Lee, 1992, 1993). It has been expanded to include the processes identified in the memory studies (Nuthall, 2000a, 2000b).

4 Interactions between students occur both within the teacher-managed public context (for example, when the class is working in groups) and within the semi-public context of peer relationships. Probably most social interaction between students occurs within both these contexts, in the sense that it is simultaneously structured by the teacher’s instructions and expectations, and by the expectations and requirements of the peer culture (Granstroem, 1996). During this interaction, the students are simultaneously aware of and responsive to both sociocultural contexts. To avoid confusion, I use the terms peer relationships and peer culture to refer specifically to social interaction that is structured by the expectations and requirements of the peer culture.

5 An ellipsis (… ) indicates where talk that is not relevant to the excerpt has been deleted.
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APPENDIX: CATEGORIES OF BEHAVIOUR IN GROUP ACTIVITIES

A. Getting and Clarifying Instructions

1. Teacher gives general instructions at beginning of activity to whole class.
2. Teacher gives instructions during activity.
   2.1 Instructions to the whole class.
      2.1.1 Teacher gives instructions about moving along.
      2.1.2 Teacher models what groups should be doing by making an example of one group.
      2.1.3 Teacher gives instructions about specific activity or corrects activity.
   2.2 Instruction to a specific group.
      2.2.1 Questions what a group is doing.
      2.2.2 Corrects what group is doing.
      2.2.3 Praises a group for what they are doing.
      2.2.4 Gives specific instructions to a group.
      2.2.5 Re-organises seating or individual roles.
      2.2.6 Re-organises the way the group is working.
3. Students read prepared instruction sheet.
   3.1 Reading instruction sheet at the beginning of the activity.
   3.2 Reading the instruction sheet during the activity.
   3.3 Asking peer about what the instructions are.

B. Interpreting Instructions and Organising Resources

1. Socially interactive interpretation and organising.
   1.1 Mutually cooperative interpretation and organisation.
   1.2 Debate and negotiation of interpretation and organisation.
   1.3 Negotiating the exchange of resources.
   1.4 Organising other children to organise resources.
   1.5 Organising who should work with who.
   1.6 Asking other students for help in organising resources.
2. Interacting with teacher about finding or organising resources.
   2.1 Asking the teacher for help to find resources.
   2.2 Getting help from teacher to find or organise resources.
3. Individually getting, arranging resources

C. Carrying Out the Procedures Required by Instructions

1. Individual organises and carries out the required procedure.
   1.1 An individual organises and carries out the procedure (others may be watching, but not contributing).
   1.2 Watching passively while others carry out the procedure.
   1.3 One person tries to correct the activity.
2. Group carry out procedure together.
   2.1 One person organises another to carry out the procedure.
   2.2 Group carries out the procedure cooperatively but without comment.
   2.3 Group carries out procedure, commenting on what they are doing (e.g., asking each other what they are doing).
   2.4 Reporting to each other what they have done (procedures).
3. Peer group talking about observations and results.
   3.1 Group talks about what they observe.
   3.2 Student tells others the results of the procedure.
4. Group talking with each other about reasons, explanations.
5. Talking with teacher about observations and results.
   5.1 Reporting to the teacher what they observed during the activity.
   5.2 Talking interactively with the teacher about observations and results during the procedure.
6. Talking with the teacher about reasons, explanations.
   6.1 Teacher asks them for their explanations.
   6.2 Teacher provides cues or a model for explanation.
7. Teacher carries out the procedure with the group, instructing them in detail, or modelling the procedure.
   7.1 Teacher goes through a sequence of activities.
   7.2 Teacher corrects a specific procedure.
8. Group carries out an incorrect or misinterpreted procedure or an accident occurs with the materials.
9. Engaging in alternative and playful activities and uses of resources.
   9.1 Individual playful and alternative activities.
   9.2 Peer interactive playful and alternative activities.

D. Peer Interaction Unrelated to Task Procedures
1. Positive peer interactions about unrelated topic within group.
2. Positive peer interactions about unrelated topic with non-group member.
3. Peer interactions involving personal conflict unrelated to activity.

E. Writing the Report
   1.1 Organising materials individually.
   1.2 Organising interactively with others.
2. Obtaining copy of instruction sheet.
3. Finding out what to write, what questions to answer, how to complete the report individually or interactively with peers.
   3.1 Reading instruction sheet.
   3.2 Asking peers about what to do in report.
   3.3 Talking with peers about what to do in report, what to write, how to complete it, what are the answers.
4. Discussing what to write in report, how to complete it, with the teacher.
   4.1 Asking teacher about what to write in the report.
   4.2 Teacher gives specific instructions to student about report.
   4.3 Teacher reads and comments on a student’s report.
5. Discussing what they have written in their report.
   5.1 Talking about what they have written.
   5.2 Talking about the mistakes with each other or teacher.
6. Writing the report.
   6.1 Copying title and questions from instruction sheets.
   6.2 Writing what they did.
   6.3 Writing, or making a drawing of, what they saw, observed.
   6.4 Writing an explanation or reason for what happened.
7. Student reads own writing just completed or from previous day’s work.
8. Reading another student’s writing in the report.

F. Spending Time Doing Nothing Active
1. Gazing round the room, looking at others working or teacher talking to another group.
2. Student pauses during activity, apparently unsure, confused.
3. Reading over previous day’s work that is not relevant.

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2. REASSESSING THE NATURE OF LEARNING IN A SCIENCE OR MATHEMATICS CLASSROOM

INTRODUCTION

The nature of learning, dominated by behaviourist models in the first half of the 20th century, became more complicated in the second half with the cognitive revolution (Harre & Gillett, 1994). In the 21st century, new paradigms for learning are emerging, making the nature and evolution of learning a site of controversy. For example, Sfard (1998) presents two metaphors for learning mathematics—learning as acquisition versus learning as participation. Others have also proposed alternative models of learning (e.g., Kirshner, 2002; Lehrer & Schauble, 2006).

These new models or metaphors, based on radically different theoretical frameworks for understanding learning, have practical and empirical implications for education. Sfard’s models contrast constructivist and sociocultural metaphors. Kirshner (2002) compares habituation (behaviourist/information-processing models) versus conceptual construction (Piagetian constructivism) versus enculturation (sociocultural) models. Case (1992) traces the historical roots of these perspectives to competing philosophical paradigms: British empiricism (information processing), continental rationalism (Piagetian and neo-Piagetian constructivism) and Hegelian/Marxist social and historical analyses (sociocultural). These distinctions are not merely important for theorising about and conducting educational research. Many educators have used them to guide instructional design, professional development and assessment.

In surveying the field of competing theoretical traditions and learning metaphors, we begin to ask whether integration is possible. Case, for example, believed it was and proposed his own version of neo-Piagetian theory that was based in continental rationalism but incorporated aspects of information-processing and sociocultural psychology. Graham Nuthall, like Case, believed integration was possible and proposed his own version based in British empiricism (e.g., information-processing psychology) and continental rationalism (Piagetian constructivism) but including aspects of sociocultural psychology (e.g., genre theory). In contrast, theorists such as Kirshner (2002) and Sfard (1998) remain, like me, sceptical that one synthetic theory of learning can be devised that is internally coherent. Instead of a single grand metaphor for learning, Kirshner proposes that educators employ a "collage of metaphors" (p. 49) to meet their practical needs when addressing a range of instructional goals.
In this chapter I critically evaluate the meaning of learning in a science or mathematics classroom and its implications for research. First, I examine Nuthall’s integrative approach to learning as exemplified in some of his late published work. Next, I contrast his theoretical perspective with that of others who prefer to work within one theoretical tradition (e.g., sociocultural) by expanding its reach and articulating its key notions. Finally, I reassess learning in a science or mathematics classroom, encompassing theoretical and methodological perspectives.

CRITICAL REVIEW OF NUTHALL’S APPROACH TO RESEARCH ON CLASSROOM LEARNING

In some of his late-published classroom research, Nuthall (2000a, 2000b) updated process–product correlational research designs for studying learning in classrooms by incorporating several innovations. The process–product approach to studying teaching effectiveness has a long history (Shulman, 1986). The earliest versions of this design were training studies where pre- and post-tests of isolated skills were used in combination with an experimental intervention aimed at behaviour change. When participants were randomly assigned to treatment and control groups, outcome differences would reveal whether the training had produced the desired effects. Later versions used intact classrooms instead of laboratories, sacrificing experimental control but including measures of instructional processes. By correlating pre- to post-test gains (outcome measures) with instructional process measures, these studies examined the behavioural changes associated with particular types of teaching. The original versions of process–product research viewed learning through a behaviourist perspective: changes in individual skills were linked to prior changes in stimulus–response contingencies. After the cognitive revolution, these designs were adapted to assess changes in logical reasoning or conceptual structures.

One innovation Nuthall employed in his process–product classroom research was to use multiple complementary methods. By collecting data on discourse from individual students, groups of students and the teacher, he examined instructional process from many perspectives and charted its dynamic characteristics. A second innovation was to adopt a microgenetic perspective on student learning to characterise as well as record shifts in conceptual networks over short periods of time (e.g., Siegler & Crowley, 1991).

Another innovation was Nuthall’s change from a behaviourist theory of learning (linking discrete classroom behaviours to discrete changes in skill acquisition) to an information-processing theory (connecting social and discursive processes to changes in long-term memory contents and structures). Finally, he examined this design from a sociocultural perspective by incorporating some of the concepts and methods from this additional theoretical approach. For example, he integrated narrative genres (Hicks, 1993; Wells, 1996) with schema theory (from information processing) to examine students’ recall in a classroom setting (Nuthall, 2000a).

Nuthall’s learning goals appeared to be conceptual change in science, as two published studies suggest (2000a, 200b). These goals are consistent with one of the
three images of science learning (i.e., conceptual theory change) outlined by Lehrer and Schauble (2006) and measured via pre- and post-test change in individual measures. Learning processes are also evaluated using data from instruction (e.g., transcripts of taped exchanges between teachers and students and field notes recorded by an expert observer).

The strengths and limitations of Nuthall’s approach can be viewed from both theoretical and empirical directions. By relying on information-processing constructs such as working and long-term memory to assess conceptual change in naturalistic environments, he could build on many years of productive research from an information-processing perspective (for overviews, see diSessa, 2006; Nuthall, 2000b). He could also assess learning in ways familiar to parents, teachers and policy makers: through individual measures conducted as interviews or paper and pencil tests.

Information-processing theory, however, was originally developed to model individual thinking processes in laboratory settings via the creation of computer simulation programs. Microgenetic studies have been used in a similar fashion in settings where many variables are controlled across sessions (e.g., tasks, participants, instructions, procedures). Although taking the study of thinking from the laboratory to complex naturalistic settings is an innovation, this approach meant Nuthall gathered data that might not complement his theoretical orientation. I agree with Sfard (1998) that “the persuasive power of data may be confined to the paradigms within which they came into being” (p. 12).

In addition, his designs assume that individual pre- and post-test measures are the best way to assess changes in the contents of long-term memory after instruction. This reliance on individual measures ignores questions raised by other investigators about the validity of these measures to assess learning in complex social settings (Cole, 1996; Polman & Pea, 2007).

Forman and McPhail (1993), for example, conjectured that some students may not demonstrate strong post-test performance after engaging in sophisticated collaborative problem-solving. They wondered whether the two adolescent students in their case study lacked sufficient interest in demonstrating their understanding of the problem in an individual post-test with a knowledgeable examiner. In an expanded study of multiple pairs of students (n = 19 dyads) working on the same task, Forman and Larreamendy-Joerns (1995) showed how collaborative problem-solving may cause students to redefine their goals and thus produce apparent regressions on individual post-tests. Only by evaluating the students’ performance on a different measure could the researchers discover the students’ own emergent learning objectives. Additional analyses of the communication dynamics during pair work demonstrated the complex negotiation process by which goals were redefined during problem-solving. Other investigators (Kieran, 2001; Tudge, 1989) have obtained similar results.

In addition, ethnographic investigators studying thinking activities in real-world settings have shown people frequently use successful strategies to solve complex problems during their daily lives that they fail to employ in more school-like settings (e.g., Saxe, 1991). Naturalistic environments are often designed to allow
people to offload much of the mental work that they need to achieve those conceptual and practical goals they cannot as easily accomplish when isolated from those environmental cues. For example, Saxe found that children selling candy on the street in Brazil relied on cultural tools (candy packages, money) as well as older children and adults to do the mathematical computations necessary to buy wholesale and sell retail. These same children, when asked to perform the identical mathematical computations in a paper and pencil format, were unable to correctly solve them. These results call into question the ability of individual test-like assessments to demonstrate a person’s conceptual competence. Instead, assessments appear to provide us with just one measure of what a person can accomplish with a particular set of resources (Forman, 2003).

By focusing on the impact of specific instructional experiences on students’ long-term memory storage, Nuthall employed Sfard’s (1998) learning as acquisition metaphor. This metaphor assumes that concepts are like entities that can be transferred from one place to another and that concepts can be linked to one another in complex structures. In a sense, this notion of mental entities makes them commodities, like money, that can be saved in a bank or moved from one investment to another. These hypothetical mental entities are private events that are not subject to direct observation such as the cultural practices or “ritualized routines” that fascinated Nuthall (2005, p. 924) late in his career.

In one of his later publications, Nuthall (2000a) contrasted explanations from sociocultural genre and constructivist schema theories to help guide his analyses and interpretations. Citing a range of sociolinguistic and sociocultural theorists, he defined genre theory as people’s use of particular linguistic forms or practices to achieve goals. In contrast, schema theory refers to mental script-like structures that organise common features of activities (e.g., the restaurant script). Ultimately, Nuthall decided, genre theory dealt only with the “surface features of students’ involvement in classroom activities” (p. 289) rather than the hidden cognitive processes and structures that are needed, from an information-processing theorist’s perspective, to explain long-term recall. He also referred to Piaget’s late work to help him explain the process of internalisation (of the structures of the physical and social world) that he felt was necessary to adequately document recall of classroom activities. Thus, for Nuthall, sociocultural theory was aimed at describing the surface features of activity, not at its deeper, hidden structural features.

THE SOCIOCULTURAL ALTERNATIVE THEORY OF LEARNING

Although Nuthall’s late work shows his openness to innovations from sociocultural theory, his overwhelming concern for understanding internalisation from a constructivist perspective (2000a) made it difficult for him to understand why many theorists substitute appropriation and/or mastery for internalisation (Polman & Pea, 2007; Wertsch, 1997). Polman and Pea clarify these distinctions.

Unlike internalization, the terms appropriation and mastery do not imply that residuals “in the head” are unsupported by tools in the world. Some sort of mental representations are appropriated by individuals intramentally and can
be applied across multiple contexts, but the mental representations do not do
the work of cognition alone … The tools that an individual needs to carry out
actions may not be available in all settings, but part of what humans do is
create or arrange their environments so that not all the work to be done
requires mental gymnastics. (p. 300)

Sociocultural theories of learning often use metaphors such as enculturation,
apprenticeship or legitimate peripheral participation to characterise learning
(Kirshner, 2002; Lave & Wenger, 1991; Sfard, 1998). For example, learning
occurs when old-timers enculturate newcomers into the valued activities of the
community of practice (e.g., tailoring). Learning involves changing one’s identity
as well. For example, the Alcoholics Anonymous community requires its members
to recognise that they are “recovering alcoholics” not “social drinkers” (Lave &

Thus this alternative perspective on learning views complex interpersonal
contexts as the sites of learning processes as well as the constraints and affordances
of those processes. If the old-timers refuse access to the community’s valued tools
and practices, then the newcomers’ learning is hindered (as it was for butchers’
apprentices in Lave & Wenger, 1991). Also, if newcomers resist learning what the
old-timers are willing to teach them, then learning cannot occur.

Historical change can also alter the processes and outcomes of teaching as
Greenfield (1999) found with children learning to weave in Mexico. In her earlier
study, Mayan mothers worked closely with their daughters, carefully scaffolding
their actions; two decades later, the daughters of her original participants were
learning how to weave from less attentive older sisters and printed paper patterns.

Thus valued cultural tools and practices during the time of Greenfield’s original
study were part of a ritualised routine of passing traditional knowledge from
mothers (old-timers) to daughters (newcomers). Through their activities, mothers
and daughters displayed their identities as members of a traditional Mayan cultural
group. Twenty years later, Greenfield found the valued cultural practices
emphasised new weaving patterns (from printed instructions that required literacy)
and a new market-economy that rewarded non-traditional patterns. One could infer
that these girls were being socialised to view themselves as autonomous agents.

For sociocultural researchers, the study of cultural practices over time is
necessary to understand what a particular social act means in context for a specific
person. For them, public behaviour is no mere surface feature: it is linked to
repeated patterns of activity in the particular culture and must be understood in this
context. This understanding is possible if one assumes a metaphor for learning as
participation (not acquisition). In addition, classroom ethnographers often employ
tools from sociolinguistics to identify the repeated patterns of activity (i.e.,
participation structures), cultural norms and discursive features that help them trace
transformations of practice over time. Finally, does the enculturation metaphor also
apply to formal schooling in science? Several science educators (e.g., Lehrer &
Schauble, 2006) believe it does.
In the 1970s classroom research based on sociolinguistics began to appear in the education literature. Green’s (1983) literature review showed the value of studying instructional processes by viewing teaching as a linguistic process. Updates (e.g., Cazden, 2001) indicate this approach continues to be active and influential. Classroom discourse research differs from the process–product research of Nuthall and others in its research questions, ethnographic methods and instructional goals.

For instance, Polman and Pea (2007) investigated when and how students take up or appropriate the scientific tools available in their classroom setting. These research questions often require qualitative analyses (using techniques such as discourse analysis) and employ ethnographic case study designs. In line with Nuthall (2005), investigators gather rich data but aim to conduct interpretative analyses instead of quantitative investigations. As Mehan (1998, pp. 247–248) observes, “Instead of asking questions that seem to imply a correlational answer … microethnographers ask questions that call for a constitutive answer. ‘What is the interactional work of … [disability, identity, school success]?’”

One new direction is to expose students to a more authentic view of scientific and mathematical practices. For more than a century, reformers have been concerned that students often fail to learn about the disciplines they study in school (Shulman & Quinlan, 1996). In science, students typically memorise vocabulary, read about scientific conclusions and practise rote laboratory procedures. The standards documents of late 20th century North America strongly criticised this overemphasis on memorisation and learning routine procedures (National Council of Teachers of Mathematics, 2000; National Research Council, 1996). One criticism was that these boring, predictable classroom activities failed to link to the creative, varied activities of professional scientists and mathematicians (Duschl, 2008; Hiebert et al., 1996).

Ford and Forman (2006) reviewed literature in science studies (history, philosophy and sociology of science) and science education to draw parallels between valued practices in science and similar practices in the classroom. They argued that both the science studies and psychology literature took a “practice turn” (p. 2). Thus the history, philosophy and sociology of science began to change through research on the activities of scientific laboratories and field stations (e.g., Kuhn, 1970; Lakatos, 1970) such that “scientific communities play an important role in negotiating what research questions count as worth pursuing, which programs of research are viewed as most productive, how debates are framed, and what drives scientific discovery” (Ford & Forman, 2006, p. 12).

Concurrently psychology scholars began to ask similar questions (Goodnow, 1990). What subjects are worth learning? Which subjects are too risky or inaccessible? What kind of person would I become if I learned this subject? The learning as participation paradigm is also relatively compatible with how these personal questions are framed. It assumes learning is an inherently social process that occurs within communities of practice (including homes and schools).
Within this learning paradigm, indices of learning are public: we can watch newcomers following the direction of old-timers or being refused access to valued activities. We can record indices of newcomers’ active or passive resistance. We can notice failures to master crucial tools or to follow established norms. We can also document the events surrounding the most disruptive or productive events—the unique situational conditions that result in a student being labelled as an “outcast” (Wortham, 2006) or “learning disabled” (McDermott, 1993).

What do we now know about classrooms where teachers are attempting to enculturate students into authentic scientific practices? A full review of that literature is beyond the scope of this chapter (see, instead, Bricker & Bell, 2008; Ford & Forman, 2006; Lehrer & Schauble, 2006). Nevertheless, a few brief examples may illustrate that connecting the science studies literature to research on science classrooms can provide alternatives to the process–product approach to studying classroom learning.

For example, Lehrer, Schauble and Petrosino (2001) argue that three scientific practices—modelling, representation and argumentation—can be successfully employed in elementary and secondary school classrooms to support students’ understanding of the nature of science. They found primary school children, with expert teacher scaffolding, can appropriate scientific tools such as graphs to help them understand answers to questions about the steepness of ramps and plant growth and decay. The researchers worked closely with experienced teachers to simulate a scientific community where students used authentic tools to investigate their genuine questions. Primary school children demonstrated their meaningful appropriation of symbolic and material tools by applying concepts such as “triangle” in radically different settings (e.g., when judging the steepness of a ramp and the growth rates of plants as depicted on graphs).

In contrast, Lehrer et al. (2001) described middle school classrooms where students had been taught to use the scientific method to evaluate the variables affecting buoyancy. However, these older students failed to appreciate that controlled experiments model factors that operate in the “real world”. Their skill mastery was not meaningful to them and was unlikely to transfer to other appropriate situations. Thus Lehrer et al. demonstrated meaningful social experiences may be more important than skill mastery or prior knowledge in explaining learning gains.

**DISCUSSION AND CONCLUSIONS**

This brief discussion of an alternative approach to studying learning in science classrooms shows that the research questions, methods and learning objectives differ from Nuthall’s. This sociocultural approach to studying learning via participation focuses on the classroom community and the complexities of student and teacher participation patterns, discourse and tool use. Importantly it examines transformations of student and teacher participation over time and documents parallels between the cultural practices of disciplinary and classroom communities. Although the investigations focus on public behaviour, these analyses are not seen
as merely examining surface features. To understand the meaning of these public behaviours, one needs to engage in thick description (Geertz, 1973). In short, local definitions of key cultural notions must be uncovered and documented.

Why do observers of classroom processes and outcomes see different things? One answer may come from investigators’ professional histories. Nuthall’s career began with a focus on “how teachers shaped student learning” (2005, p. 896), followed by an interest in the phenomenology of student engagement and learning in classrooms. By contrast, I first focused on student participation patterns in problem-solving activities (Forman & Cazden, 1985) and only later incorporated an interest in the teacher’s influence on students’ discourse and reasoning (Forman & Ansell, 2001). Early in my career, I was fascinated by ritualised routines in classrooms before Nuthall decided to investigate them. I also focused on the contrasting behaviours of “successful” and “unsuccessful” students (Forman, McCormick & Donato, 1998). Rather than individualistic theories of learning by acquisition, it was sociolinguistic and sociocultural theories of learning by participation that helped me understand how some students were positioned as “good mathematics thinkers” and others as “average or struggling learners” (Yamakawa, Forman & Ansell, 2009).

If Graham Nuthall and I had observed the same elementary school classroom, would we have seen the same thing? I doubt that we would. Nuthall would have been interested in understanding which classroom practices changed the contents of individual students’ long-term memory. For him, entities such as working memory, schemas, long-term store were part of the learning process and outcome, and individual measures of performance would best assess the long-term impact of instructional experiences. His interest in classroom social processes would have focused on their connection to improved test performance.

For me, classroom dynamics and individual performances are inter-related but neither is a better measure of students’ mastery or appropriation of new knowledge. Although sharing an interest in improving student performance (in the classroom and beyond), I assume changes in performance across contexts vary, depending on access to social, material and symbolic tools and on prior experiences and future expectations. I would pay close attention to the unfolding of classroom norms and practices over time and would try to understand the local definitions of “success” and “failure” in this particular setting. For me, the culture of the classroom is an important aspect to understand and document; for Nuthall, the contents of students’ mental structures would be a critical feature to explore and record.

As I argue above, Nuthall’s classroom research seems to fall into Sfard’s (1998) category of learning as acquisition whereas my own follows her metaphor of learning as participation. In addition, in his late classroom work, Nuthall tried to integrate across three theoretical perspectives—information-processing, Piagetian constructivism and sociocultural. Nevertheless, close examination of Nuthall’s research reveals a preference for one approach. Information processing seemed to predominate because of his interest in understanding the impact of classroom events on students’ long-term memory of academic content.
Can investigators successfully integrate across perspectives on learning? Sfard (1998) argues the field of learning theory should be big enough to allow at least two different metaphors to co-exist, just as other fields endorse competing perspectives. She proposes that investigators choose their metaphor depending on their goals: some use the acquisition metaphor to model, via computer, human thought processes; some use the participation metaphor to understand the complex interpersonal dynamics occurring in a naturalistic setting. I agree with Sfard’s conclusion that competing metaphors are likely to continue to co-exist as we try to make sense of the broad phenomena of human learning in complex environments such as classrooms. Similarly Kirshner (2002) argues educators should adopt a cross-disciplinary position in selecting a theory that best fits their learning goals in a specific situation. Thus researchers may need to work within one learning framework to achieve theoretical coherence, whereas teachers may need to use several learning models to achieve their pragmatic goals.

NOTES

1 Sociocultural psychology and cultural historical activity theory are often used to refer to a family of theories derived from work of Vygotsky, Leont’ev and Luria in Russia (see Daniels, 2008).
2 For example, Nuthall used the word “acquire” in one of his titles (2000a).
3 This critique seems to equate sociocultural theory with behaviourism.
4 The quotation marks around words such as “outcast” indicate these are social constructions, not factual descriptors, according to the authors of these sources.

REFERENCES


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