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ABSTRACT

The development of appropriate science learning environments for young children is an urgent and justifiable concern of many. By applying combined features of cooperative learning and informal inquiry to an investigation of shadow formation, researchers were able to observe closely the natural behaviors adopted by twenty-seven students aged 7-9 years old as they engaged in a quest to understand the scientific task placed before them. Four research questions were investigated: (1) How does this learning environment support children as socially and personally responsible communicators, social constructors of knowledge, and inquirers without expectations of external rewards?; (2) Does the learning environment remain, as designed, inclusive?; (3) What ideas do some young children express about shadows before, during, and after our lessons?; and (4) What are some probes which can assist children to question their ideas about shadows and indicate whether conceptual learning about shadow formation has occurred, or is occurring? The results were used to hypothesize that environments designed to promote holistic social, emotional, and conceptual learning of physical science in young children, may eventually attract committed and ethical students to scientific careers and lead to questioning societal norms which define some groups as without power or h(.,. (ZWH)

"The shadow is there and you just can't see it" - A learning environment for young children to investigate shadows

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ABSTRACT

As part of an investigation into developing learning environments in science education for young children, I amalgamated features of cooperative learning and informal inquiry and set them in an inclusive context. Here I describe how this environment supported children (aged 7 to 9) in developing their identities as communicators, inquirers, and social and individual constructors of knowledge, as they studied shadow formation.

Children responded to the open opportunities available as they investigated shadows; some spontaneously carried out controlled scientific inquiry; many enjoyed engaging in intellectual discussion while learning cooperatively; some developed new insights into shadow formation; some constructed gendered identities according to societal norms; most bound their group so that it offered social and emotional support to its members. I describe children's developing views of shadow formation, how I gained access to their reasoning and I also consider some counter examples of how a few children participated in this learning environment partially transforming it, to their own potential disadvantage.

In discussing educational values of this learning environment, I offer suggestions to educators of young children, among which are: firstly, that absence of expectation of extrinsic reward may be a key construct; secondly that "light traveling in space", a seminal idea, can be embedded within this environment; and finally, that educators consider sanctioning copying as a learning strategy for children's legitimate peripheral participation in classroom communities of practice. I also hypothesise that environments designed to promote holistic social, emotional and conceptual learning of physical science in young children, may eventually attract committed and ethical students to scientific careers and lead to questioning societal norms which define some groups as without power or hope

INTRODUCTION AND THEORETICAL PERSPECTIVES

Emergent theories of child development question the horticultural metaphor implicit in Piaget's genetic epistemology, that there is an underlying intellect, present at birth, which will flower in full predestined glory, if nurtured (McCrone, 1993). These emergent theories have their origins in Vygotsky's social theory of mind (Vygotsky, 1978) - we have evolved a brain which is capable of perception, awareness, recognition and associative thought, but which depends upon its culturally determined inner voice, for complex thought, creativity and emotions (McCrone, 1993). A theory which holds that children's intellectual development is socially and culturally determined, rather than pre-ordained according to a stage theory, has implications for science education. I believe a major implication is that educators should design and research appropriate science learning environments for young children. In Australia, this is a relatively new area, (Fleer, 1990), compared to the extensive research base on learning science in secondary and tertiary settings.

Young children appear highly motivated and curious as they explore the natural world. As they develop language and its accompanying inner voice, their brains are plastic (Gardner, 1985). Gardner (1985, p. 36 - 48), considers principles of canalization and plasticity, reviews evidence drawn from a number of studies and concludes that:

> There is good reason to believe that, with suitable modifications, these principles can apply to the ways in which human beings develop certain cognitive systems, and learn to achieve certain intellectual skills, in the process of following certain paths rather than others (p.48).

One potential advantage for beginning science education early is that we can use plasticity of young minds to promote an early intellectual mode of inquiry. To better understand why this might be necessary, I briefly turn to examples of secondary and tertiary science teaching, where there are well documented barriers to successful science learning (Fensham, 1988).

In secondary school science, constructivist teachers (e.g. Bell & Pearson, 1991) aim to change children's intuitive views of physical and biological phenomena (e.g. in Osborne and Freyberg, 1985), to scientists' views, but they have had variable success (e.g. Cosgrove, Osborne and Carr, 1983, Fetherstonhaugh & Treagust, 1992). An assumption which may partly explain secondary students' tenacious hold on their intuitive ideas is that their brains are no longer plastic. Students may then be less influenced by others' ideas which conflict with their own implicit, unquestioned assumptions about the world. I also conjecture that older students may be not only less able, but also less willing than younger learners to risk undertaking the process of critical examination of hitherto unexamined assumptions about their world. Some evidence for secondary learners' unwillingness to risk alternative ways of participation in classroom learning, comes from the initial year of the PEEL project (Baird & Mitchell, 1987) and for tertiary learners, from a study of preservice primary teachers (Segal & Cosgrove, 1992).

In addition to theories about difficulties of effecting conceptual change, some educators assume that children find science difficult to learn because of their cognitive limitations; affective and social factors which are important to their lives are ignored (Claxton, 1989; Shapiro, 1989). A related criticism is that science curriculum planners have not planned for development of cooperation and social relationships (Kutnick, 1989). These reproaches, although valid, do not address a fundamental assumption of school science, that of equating learning with increasing subject matter knowledge.

Rather than defining learning as acquiring knowledge, Lave (1992) theorises that studies which assume learning has not occurred because there was no conceptual change, ignore other dimensions of the relationships between the learner, subject to the learned, and the classroom culture. She suggests that different research questions should be asked, not whether children have learned, since learning is an aspect of all activity, but what they have learned (Lave, 1992, p.2). By theorising learning as giving children their "specific historically, culturally forged identifies that engage in learning in particular ways", Lave locates characteristics that are commonly assumed to belong to an individual, such as engagement, alienation, ignorance, expertise, as attributes of communities of practice. This means that "the learner and 'subject' to be learned are relations among many things at the same time" (p.5). Lave points the way to more general solutions to science learning problems.

I therefore need to deal with two principal issues at once in designing an appropriate physical science learning environment for young children. I want to encourage learners to engage in an habitual mode of inquiry into their assumptions about seminal science ideas, and prevent loss of flexibility and plasticity at too early a time. This part of the learning environment is cognitive. At the same time, I want to question the unproblematic way in which gaining science knowledge, by conceptual change, metacognitive strategies or other methods, is viewed as the most important (or only desirable) outcome for science lessons (e.g. Baird & Mitchell, 1987). I wish children to develop an interrelated sense of value for the science that is to be learned, for the processes by which it can be learned, for their identities as participants in building a classroom culture which is considerate of everyone's social and emotional needs and for which they and their teacher are responsible.

To approach the first issue, I need to find out if certain seminal ideas, central to a scientific discipline can be embedded in a context which can be understood at an early age. My optimum learning environment would need to assist children to articulate and question their views about such central ideas, before their ideas become inflexible. For my chosen topic, light, one such central idea is that "light travels" and one context in which it may be embedded is shadow formation. This concept of light traveling underpins understanding all major concepts about light and associated technology- shadow formation, reflection, refraction, optical instrument design, vision, colour (Andersson & Karrqvist, 1983; Guesne, 1985).

To investigate the second issue, I need to design a shadows learning environment which is inclusive, social, motivating, puzzling and pleasurable, so that it supports children as they move towards full participation in that environment. Full participation would imply entering the context, shadows, in a mode of intellectual, yet joyful inquiry, forming mutually supportive social relationships, and enhancing knowledge and sense of self, in a positive way. Absence of expectation of extrinsic reward underpins the affective nature of the participation.

This research is unique, in that although children's ideas about shadow formation have been described using individual interviews (e.g. Piaget, 1930/72; Feher & Rice 1988), there has not been any study of ways in which young Australian children can be assisted to articulate and develop their ideas on shadow formation in a learning environment designed to assist them to move towards full participation in their classroom community of practice.

DESIGNING A LEARNING ENVIRONMENT

The learning environment I have designed is woven from three strands:
the learning is to take place in cooperative groups,
the learning is to be by informal inquiry, and
the learning is to be located in a familiar and inclusive context - shadows.

Cooperative learning

Because I did not wish to reproduce conditions which lead to alienation in secondary science lessons (e.g. Kelly, 1987), I sought ways to reduce competitive learning by accentuating cooperative learning. I prefer the Vygotskian view of cooperative learning (Slavin, 1987), that knowledge can be socially constructed (Resnick, 1991) without accompanying extrinsic rewards, as I see this as a more natural way in which young children learn. My view of cooperative learning also incorporates some strategies for development of social growth (Johnson, Johnson & Holubec, 1990). I describe these strategies in the section on methodology.

Informal inquiry

In naming the second strand of my model, informal inquiry, I link it to Dewey's (1938) and Schon's (1992) exposition of inquiry. As Dewey conceived it, inquiry is transactional, open-ended, and inherently social. "Inquiry begins, Dewey believed, with an indeterminate (i.e., confusing, obscure, or conflicting) situation and goes on to make that situation determinate. The inquirer does not stand outside the problematic situation like a spectator; he (sic) is *in* it and *in transaction with* it." (Schon, 1992, p 122, italics in original.). Strongly implied in this conception of inquiry is a fusing of intellectual and emotional factors. This occurs in informal learning, whereas these factors are artificially separated in formal school learning (Hennessy, 1993; Brown, Collins & Duguid, 1989). I give form to this aspiration by adapting Biddulph and Osborne's (1984) interactive teaching model.

Familiar and inclusive context

Early learning is situated in a social world, in which language, interaction and cognition are inter-related and interdependent and from which meaning can be derived (Bruner & Haste, 1987). From a social plane, according to Vygotsky, (1978) learning moves to the psychological world of the learner. There, further meaning can be developed, leading to deep understanding (Cosgrove, 1989). I assume here that the context of shadows, which can link children's worlds of home, play and school, is an inclusive context from which all children can develop meaning, as it does not appear to hold hidden advantages for children of particular gender, race or social class.

Thus my purpose has been to construct a learning environment which would enable young children to engage in science experiences which are enjoyable from an intellectual, social and emotional perspective. I am particularly interested in how children actively engage in forging their identities as inquirers and in the relationships they construct with each other and with the context. In particular, I crystallised the following research questions:

1 How does this learning environment support children as:
   1.1 socially and personally responsible communicators,
   1.2 social constructors of knowledge,
   1.3 inquirers, without expectations of external rewards?
2 Does the learning environment remain, as designed, inclusive?
3 What ideas do some young children (aged 7 to 9) express about shadows before, during and after our lessons?
4 What are some probes which can,
   4.1 assist children to question their ideas about shadows,
   4.2 indicate whether conceptual learning about shadow formation has occurred, or is occurring?

DESIGN AND PROCEDURES OF THE STUDY

School background

The school in which I carried out this research is situated in a middle class area of Sydney. The children are mainly of Australian or European background, with few children of language background other than English. Two teachers volunteered to participate in the study, and although it was my original preference to be a participant observer in their classrooms, both preferred that I teach their classes. In this paper I report on findings from the Year 2/3 Class, (Year 2: N= 19, ages 7/8; Year 3: N = 8, ages 8/9); findings from a Kindergarten class are reported elsewhere (Segal & Cosgrove, 1993).

Year 2/3 classroom was small, attractive and naturally lit, with children seated at movable tables arranged in rows. Limited space meant that the tables reached almost to the front of the room and almost to the back. Samples of children's work adorned the walls and each child's work was stored in a brightly coloured tote tray, arranged in shelves along one wall.

Year 2/3

The class had not previously worked in cooperative groups. The class teacher agreed with my suggestion to have three children in each group and arranged nine groups, with the grouping mainly based on existing friendship or perceived compatibility. Exceptions to this were Year 2 Carrie, judged by her teacher as intelligent and responsible, placed with two boys who tended to have a less serious attitude to school work; Year 2 Paul, from China, who had been in Australia about one year, placed with two Year 3 boys; and Year 2, Katy, placed with two Year 2 girls. The teacher tried to ensure that these latter children, who had difficulties with social relationships, were with tolerant, mature others.

When the groups were working, it was part of their responsibility to move desks and chairs so that they were able to face each other, or to clear a space for experimentation. As the classroom was so small, some groups were given permission to move desks and themselves into an adjacent resource room.

Methodology

There were seven half hour sessions with Year 2/3 over a four week period. Session 5 was able to be extended an additional fifteen minutes. One week after the lessons, I conducted conversational interviews ranging from 15 to 25 minutes, with each group of children about their experiences during their lessons and about their views on shadow formation.

I decided upon three cooperative group roles of leader, reporter/writer and equipment manager. To assist understanding of role requirements, I kept my oral instructions to a bare minimum and typically asked one group to model roles, as I explained them, in front of the class. For later reference, I handed to each group a folder containing pages for each role in that lesson, with each page being typed in large print and containing two or three guiding steps. One constant factor in each role was the instruction to be kind to each other, and I explicitly asked reporters to tell the class how their group members were kind. Children rotated cooperative group roles, with each child staying in the same role for two consecutive lessons.

In introducing the unit to the class, I suggested that the class could role play a large group of scientists divided into teams. Activities in each session, and their purposes, are briefly summarised in the table below. During this time, there was unseasonable, very heavy rain, so that other than the first two sessions, the order of doing activities inside or outside was determined by the weather.

TABLE 1: LESSON SEQUENCE IN YEAR 2/3

Session	Summary of children's activities	My Purposes were to:
1	Observed modeled group conversation to choose name for group. In small groups, offered suggestions in turns, and then chose a name for group, by consensus. Stated what they liked about working in their group and how they were kind to each other. (A standard requirement for each session.) Prepared a list of what their group thought that scientists do. Reporters told class names of their groups.	Model a group discussion in which everyone is encouraged to participate. Introduce cooperative group procedures designed to build group spirit and to introduce group roles. Accustom children to presence of recording equipment. Prepare for role play of being a class of scientists who wish to find out more about light and shadows. Introduce the notion that scientists work in groups and share information.
2	Completed list of what scientists do. Reporters shared information with class. Drew a group sketch of a scientist.	Same as session one, and: Reinforce role requirements and kindness aspects, by reporting specific and positive observations from yesterday. Give more practice on roles and working together to complete one product.
3	Observed modeled discussion. Conducted group discussion in which leader asked each member in turn what they know about shadows. Leader asked follow up question to clarify understanding. Used torches (flashlights) and small toys (attractive for boys and girls) to make shadows. Reported observations to class.	Model group discussion in which children need to listen to each other, and ask for meanings if necessary. Increase children's knowledge of group processes, to support everyone's participation. Obtain record of prior views of shadow formation. Allow time for exploratory play, and agree about what has been learned, so reporter can tell class. Give children access to ideas of others and practice in speaking in front of peers.
4	Individuals wrote down how they thought their shadow was formed. Class went outside to make observations of shadows. Reporters share insights with class.	Assist children to articulate views in writing. Assist children to link shadow formation with presence of a light source (flashlights or sun). Develop view that sharing knowledge is useful.

5	Wrote a team statement about how they thought shadows are formed. Group discussed what questions they wished to investigate about shadow formation. Reporters shared information with class. Groups used additional resources (coloured and clear cellophane, coloured pipe cleaners, coloured tissue paper, pop sticks, Al. pie plates etc. to further explore and investigate their own, or other children's questions (from my supplied list).	Give children further practice in discussion and listening to each other's views, and questioning each other. Give opportunity for developing views to be articulated. Move inquiry on, to follow children's interests. Stimulate further play, exploration, and enjoyment.
6	Group continued investigations with equipment. Most worked through all of the eight questions which were supplied. A few investigated their own questions. Wrote on prepared sheet, what they did and what they found out (optional). Reported investigations to class.	Stimulate more purposeful, focused inquiry to broaden ideas - e.g. checking relative distances between objects, light sources and screens for effects on shadow sizes, varying types of screens, types of objects etc. Give practice in providing written record (but this was not stressed, as children wrote very slowly and laboriously. I did not want to take time away from practical inquiry.)
7	Prepared group drawing of one investigation, showing where they thought the light was, by shading the region in yellow. Display of drawings and final class discussion about what they thought they had learned.	Give children additional means of representing their understandings. Provide me with further access to their thinking about whether light travels, as I chatted to them as they worked and as they made decisions about where the light was.

Regrettably, lesson duration and numbers of lessons were constrained, as timetables of two teachers, additional class arrangements for Scripture, swimming lessons, Italian lessons, parent-supervised sessions of problem solving, school testing etc., had to be meshed with my University teaching hours and commitments.

I designed data gathering methodology within a naturalistic research paradigm (Lincoln & Guba, 1985; Erickson, 1986) and operated in dual roles of teacher/participant observer.

In summary, my data sources are:

1 Observations and field notes about children in the classroom prior to the research. During this period, I was able to become acquainted with, and accepted by the children and teacher, and accustomed to class procedures.
2 Field notes and transcribed audio and video recordings. Each group of three children had a tape recorder which they controlled themselves. Final group conversations were all videoed. I was the main classroom videoer, with some children's help. On two lucky occasions, University colleagues assisted.
3 Children's written records of ideas and drawings, as formulated individually and collaboratively.
4 Field notes of conversations with the School Principal, two parent helpers, (present for some lessons), the class teacher (who unobtrusively assisted during all lessons) and other researchers who viewed some of the video tapes.

Analytic procedures

As my research questions are interdependent, I will describe situations and cite children's conversations which bear on more than one question at a time, using children's voices and my own to create thick, interpretive descriptions (Geertz, 1973) and to narrate themes which emerge from my data. My analysis will also be layered: sometimes the description is from or about, a single child, sometimes it evolves from a group and sometimes from the whole class.

I propose using Lave and Wenger's (1991) theory of situated learning to add a further interpretive layer to my analysis, but I first need to clarify answers to two questions which come to my mind. The first is: Is it legitimate to regard a school class as a community of practice? Assuming that I can justify the legitimacy of the first question, my second question is: Because I did not observe this class over the full school year, can I use this theory to comment upon and interpret a limited, stroboscopic snapshot of the class as they participate in my study?

To tackle the first question, I hypothesise (from my background as a secondary science teacher) that a class can be regarded as a community of practice, as over a year, certain principles, values, and shared understandings of authentic classroom practice for that class and teacher emerge. It is also possible, that a nucleus of children, having been together in the same class the previous year, could take the roles of old timers, with children new to the school, and to that grouping being newcomers. Developmental and transformational cycles of newcomers moving towards central participation and thereby becoming old timers, could change the community over time, as theorised for non school settings (Lave & Wenger, 1991).

In arguing for a positive answer to my second question, I find that the notion of legitimate peripheral participation is useful as a means of describing the extent to which children participate differently in various components of the learning environment.(e.g. as a member of their small group, as a member of a class in traditional mode, as a member of the class when reporters were in action.) I am able to comment on some transformation of these components during my study, even though I cannot analyse changes in the classroom community over this short time.

FINDINGS AND DISCUSSION

Communication, social construction of knowledge and inquiry were aspects of many activities and conversations and these both composed and transformed the designed learning environment. As inquiry in cooperative groups was a design feature of the environment, I begin my analysis by first focusing on cooperative groups, then I move to the class, in the reporting phase, and finally, I examine how some groups and individual children constructed knowledge and identity within this learning environment.

Cooperative groups

In general, audio and video tape recordings indicated that most groups thoughtfully discussed issues when asked to do so; children supported each other in their assigned group roles; in their small groups, children were serious investigators outside in the playground, they enjoyed producing one drawing per group. Without exception, children behaved responsibly: no equipment was lost or damaged; small groups arranged their tables for group work and packed up speedily near the end of the lesson for the reporting stage.

I consider that my modeling of conversations was an important aspect of the social and intellectual learning environment I was trying to create. In session 1, modeling gave children space in which to build a team spirit and to bind their group. In session 3, modeling gave children a structure within which to develop an intellectual language for articulation of ideas, for clarifying ideas of others and for constructing knowledge of appropriate and responsible ways to participate in small groups. This more formal aspect of my learning environment contrasts with the informal inquiry framework and the presence of both aspects helps to cater for children with varying needs for structure and guidance. I illustrate the importance of all three aspects in the conversations which follow.

Building a team spirit In the first activity, all group leaders easily followed the modeled pattern of asking for suggestions for a group name from each member in turn. In one group, sustained laughter and camaraderie established through one member's (Vanessa) infectious good humour and first suggestion of "Chimney" influenced fellow members to participate mischievously, as they suggested names that they found hilarious - "Light bulb", "Lightning" before they eventually decided upon "Camra Flash". Vanessa, was so pleased with this choice, that she repeated her statement, initially made to fellow group members, "We think of good names, don't we - Camra Flash." to me later in the lesson. Significantly, although it was her original suggestion, she included the group in the thinking process, using "we", rather than "I" on both occasions.

In addition to Camra Flash, conversations from five other groups showed similar early signs of mutually supporting each other's legitimate participation in group tasks, inquiries and play. These early signs proved to be a predictor, as all these groups remaining task oriented within their own framework of zest and satisfaction, throughout. A willingness to follow the structured discussion guidelines modeled for the class was evident in all groups by the third session, even where there were other irreconcilable difficulties due to differing personalities and interpretations of task as play.

Structured guidance I introduced the third lesson by explaining that the group leader should ask members in turn, what they knew about shadows and should also ask a follow up question, aimed at clarifying the answer given or trying to elicit more information. After one group modeled this for the class, tapes of ensuing discussions indicated that most group leaders proficiently and sometimes innovatively, followed this instruction. In this group of three Year 2 children, Patrick is the designated leader for the first time and in their conversation, I indicate where children are following my modeled pattern.

Patrick	Don, what do you think about shadows? *(Using member's names, as modeled)*
Don	Um well, when you're kind of walking in the sun, you can see your shadow and whatever you do, um, the shadow does it.
Patrick	Why do you think that? *(asking his follow up question)*
Don	Um, I don't know.
Patrick	Carrie, what do you know about shadows? *(Following instructions by asking the next person in turn and using her name)*
Carrie	I know that when, at night when you're reading and light's on it a spot where its normally dark in the day, the light reflects on the spot and that makes a shadow. *(Pause)*
Don	You've got to ask what she thinks about that. *(Reminding his friend about the next step)*
Patrick	Why do you think that and what do you mean by like its dark in the day? *(Showing that he had listened to Carrie's answer and asking a very plausible double question to clarify his understanding.)*
Carrie	Well, what I mean about dark in the day is that spot doesn't get as much light from the sun as like a light does. Only by a lamp, otherwise.
Patrick	Patrick *(calling on himself)*
Don	No you just say "What I think about shadows..." *(guiding and correcting the protocol)*
Patrick	I think that shadows are when you like, if you're hiding behind a tree, people could find you if its a really sunny day. Like if you're playing hide and seek.
Don	What do you mean about... *(really showing his understanding of the model, by recognising that some one needed to ask the leader a question)*
Patrick	I mean like if you're in the sun and if you're behind a tree and the shadow's on one side and then like they will see your shadow, whoever's in.

In this conversation, Don is taking on a role of expert follower of the model, even though Patrick is leader. He prompts his friend to make correct moves, thereby socially constructing within their setting, knowledge of the modeled discussion process. My interpretation here is Vygotskian, with Don, a more expert peer, working within his friend Patrick's zone of proximal development (Vygotsky, 1978), assisting Patrick to complete a task that Patrick could not complete alone.

In other conversations included in other parts of this analysis, children reveal implicit and explicit knowledge of how to work constructively in a group. For example, when I asked a group of Year 2 girls in their final interview if they could think of something that they learned from each other, my intention was to elicit knowledge of shadow formation, but Sandy interpreted knowledge more socially.

Sandy	How to look after each other when its our go, be kind and having turns and being shareful.

Sandy's comment supports my view that it is important to make the supportive and affective component of the cooperative learning strand of my model explicit. She has internalised a socially constructed view of "kindness" in a small group setting and has been able to articulate her understanding. Her use of social knowledge as an example of what she had learned also shows that this young child has not yet developed a narrow view of knowledge as primarily cognition.

This speaks to teachers whose classrooms have been more traditionally arranged in whole class settings, who believe that children of this age, with little experience of working in small groups, cannot be trusted to do so. Group cohesion, which most groups created as a characteristic of their learning environment seemed to be an important contributing factor to their involvement in the tasks, as did the motivating role of inquiry.

Informal inquiry In informal inquiry, not only do children inquire, but they also formulate their own task. Teachers often remain unaware of the tasks that children formulate, even when they are supposedly following teachers' instructions (Newman, Griffin & Cole, 1989). Children can be construed, for this reason, by their teachers and themselves, as poor learners. The reality of their unintentional placement in situations of having to formulate and solve more than one problem can lead to different interpretations of their abilities (Newman, Griffin & Cole, 1989).

In this learning environment, there is ample opportunity for children to decide upon their own problem, without risk of "being wrong". I cite two examples of informal inquiry from Camra Flash. The first example is extended, as it also shows how the three sections of my first research question are interrelated. In the second example Camra Flash plan and carry out a scientifically controlled experiment, under my informal inquiry conditions. These examples, together with continuing inquiry and comments of children made during final interviews support my decision to eliminate external rewards from my learning environment.

In the third lesson, groups were told that after they wrote their ideas about how they thought shadows were formed, they could then get an equipment box to make some shadows with torches and little toys.

The conversation below is an excerpt from a longer conversation and is indicative of the way in which Camra Flash framed all tasks to socially construct opportunities for increasing implicit knowledge about working cooperatively together and explicit knowledge about shadows. Underpinning these processes was the informal inquiry in which the girls became engaged.

At first they brought the equipment back to their position near a window, but then, realising there was too much light, decided to move.

Vanessa	Let's look for some shadows.	
Ellie	I have to collect an equipment box	*(As equipment manager)*
Vanessa	Right, all right let's all have one.	*(Sharing what was in the box)*
Mary	Now we'll take that out.	
Ellie	I can't work here.	
Vanessa	Yes, I can see something like a shadow.	

Ellie	Yes there's a shadow.
Mary	Yes, I can see a shadow too.
Teacher	See any shadows?
Mary	Let's try in there.
Vanessa	Where, somewhere darker?
Ellie	All right, wait, wait we've got to take the box with us.
Mary	I'll carry them.
Vanessa	Let's try to make one all together - the biggest shadow we can.
Mary, Ellie	OK

Throughout their conversations, members of this group use "we" and "us" constantly. When they switch to "I", the statement was usually an implied invitation to other members to repeat an activity or observation, to confirm or add to knowledge. Their social task engagement was at such a high level that they did not respond to their teacher on the tape, (although they may have responded non verbally.)

A little later in the same conversation, they began to make inferences about their observations, attending to each other's verbal descriptions.

Vanessa	I'll move him closer and it becomes clear, doesn't it?
Ellie	Yes.
Vanessa	As you move it closer, it will become different sizes, see mine's shadow there.
Mary	Yes, let me try now.
Ellie	As you move it closer, it gets lighter.
Vanessa	You mean it gets clearer.

After more investigation, Vanessa introduced a variation by beginning to re-cast the experiment into a mysterious game.

Vanessa	Look, magically I'll move it. See mine moves magically.
Ellie	I know how you do that Vanessa.
Mary	If your light moves, the shadows change sizes.
Ellie	Hey, lets put that onto the list. Come on.

They added to their list, co-constructing this knowledge situated in social and scientific practice:
"As the light moves, the shadows change size."
"As the light moves closer, the shadow gets darker."

Social cooperation, listening to each other, high task engagement and a little fun created here opportunities for learning by informal inquiry, in which all three girls mutually supported each other's participation. The girls in their setting created additional social growth opportunities for learning how best to manage a task in a group. They independently made their decision to change their location when it was too light near the windows to make shadows; they co-participated in their investigatory activities and after everyone had had sufficient opportunities to clarify understandings, they agreed about what was to be recorded for later reporting to the class.

This conversation reminds us how impossible it really is to disentangle interwoven threads of scientific knowledge, (i.e. the information about shadow formation), the reasoning process inherent in obtaining that knowledge, social knowledge, (i.e. implicit knowledge about supportive communicative structures set up in their group) and use of communication structures, some of which involve informal inquiry.

Camra Flash, like all groups, made important decisions about their learning and participation independent of their class teacher and of me, throughout the project. They did not consult adults about what should be recorded on their lists for reporting; they displayed no anxiety about whether they were carrying out their investigations in the manner intended by adults; they did not inquire as to whether their suggestions for shadow formation were correct or incorrect. All these actions contrast markedly with those of secondary students (Baird & Mitchell, 1987) and of our pre-service teacher education students (Segal & Cosgrove, 1992), who were extremely concerned about the relationship of their learning to their assessment.

I claim that the informal inquiry strand of my learning environment subtly adds strength to social ownership of activity in this setting, supports taking risks (in the form of independent decision making) as a natural part of deciding about tasks without an overlying reward structure, and sustains social growth and group cohesiveness. It can also lead naturally to controlled experimentation, the delight of science educators.

Towards the end of their time outside, Camra Flash decided to test the temperature of ground in shadow compared to the ground out of shadow. They used their hands to do this.

First Ellie stated an hypothesis.

Ellie	The hand that is off the shadow gets warmer.

The hypothesis was put to a controlled test, as the three girls knelt, placing their hands on the ground.

Mary	Lets try it ourselves.

The result is stated and it appears as though the hypothesis is not supported.

Mary	No it doesn't. This is getting freezing cold and this is getting, yeah hot.

An inference is made.

Ellie	One gets warmer than the other.

Sometimes unexpected inferences are made.

Vanessa was carrying out the same test, a little apart from her fellow investigators and showed me a different result, which she subsequently reported to the class.

Vanessa	My group found out that if you're on your shadow and you put one hand down on the shadow and one hand not, when you lift them up, the hand that was on the shadow has some scratch marks and the other hand has bumps.

Inquiry outside, in a familiar playground setting, with the sun appearing and disappearing behind clouds, seemed to inspire some children to look closely at their shadows in ways which I regard as quite sophisticated. An example comes from a group of three Year 2 boys, close friends, who were keenly interested in science. Andrew explained his insights to his friends.

Andrew	I just found out something. I found out, it depends how strong the light is,
Ross	Yes.
Andrew	and which way it's coming from.
Ross	Yes?
Andrew	The stronger it is, the darker the shadow gets and the lighter the sun gets the more you can't see it and then um with the further down the light gets, the longer your shadow gets.
Ross	Oh, I see.
Andrew	Cos, if the sun's up there, the shadow will be up to about here, but when it's down to about there, the shadow could be up to that line.
Dick	Oh.
Andrew	You know in the afternoons, when it's real.., the light's in.., your shadow is up to there.
Dick	Oh yeah.
Andrew	The sun's over there - the sun's right over there.
Ross	Yeah, look how small the shadow is.

When Andrew reported the group's findings to the class, he added additional information that he had read about "shadows lengthening" in an adventure book, *The Hobbit*. *The Hobbit* is indeed deeply descriptive of shadows. For example:

> By the time the wizard had finished his tale and had told of the eagles' rescue and of how they had all been brought to the Carrock, the sun had fallen behind the peaks of the Misty Mountains and the shadows were long in Beorn's garden. (p. 131).

Not only did Andrew's report make it a little clearer how he constructed some of the knowledge he passed on to his group and to his class, but it also served to emphasise the links that my chosen context has to settings outside the classroom and to the lived-in world.

I now move from analysing small groups engaged in inquiry, to their reporting of it.

<u>Reporting to the class</u>

As reporters, children rushed importantly to the front of the room, seemingly eager to take centre stage. This apparent enjoyment did not seem to be shared on all occasions by some restless listeners in the class audience. Children questioned about the reporting stage, did not think they had gained much knowledge by listening to others - they attributed what they had learned mainly to their own experimenting and to small group discussion. When asked to recall what they had learned, a few children mentioned original experiments of other groups and experimental results reported by others which conflicted with their own. One group mentioned that Katy, as reporter, had copied their idea.

Some needs of two children, Paul and Katy, did not seem to be supported by participation as reporters. Although Paul twice stood in front of the class with other reporters, when it was his turn to speak, he remained silent, appearing embarrassed or shy and as though he could not remember what he was going to say. I tried to assist by asking him telling him that anything he said would be acceptable, but this did not help. One of the other boys in his group, then volunteered to deliver their group report. I will say more about Paul's situation in his group later.

Katy's circumstances were different. She was a willing reporter, speaking fluently about her group's findings and she, unlike some others, remembered to report on both occasions about group member's kindness to each other. On one of these occasions, she also gave the class details of how one of the members had been <u>un</u>kind to her (in spite of this aspect of the reporting as having been introduced as reporting kindness, <u>not</u> unkindness.). As a child rejected by many in the class, participation as a reporter would not have assisted her socially by further constructing her identity as telling tales about other children, or by being thought of as someone who copied cherished ideas of others.

The reporting stage offered two main ways of participating as a communicator: in active communication, developing a sense of self as a reporter in front of the class, or in passive communication, by listening as a member of an audience. Children who chose other ways of participating alerted me not only to their differing personal and social needs and learning styles, but to my need to think about how to re-frame such a stage. Rather than asking children to pay attention, (as I did at the time) and thereby constructing lack of attention as a fault in an individual, I suggest that inattention is a property of this transmissive setting. It can be addressed by involving participants (and privately, individuals like Katy) in a discussion of this part of the environment and its purposes. All participants can identify benefits and problems, seek solutions to problems, and then take responsibility for implementing solutions.

I turn now to my final analytic category, construction of knowledge by groups and individuals. By including individuals, I do not imply that I can easily separate their psychological environment from their social environment. Conversations such as those reported above occurred in all class groups, and served not only to enhance social growth and social construction of knowledge, but also to form connections between children and their science knowledge, making their inquiry social, personal and enjoyable. Nevertheless, science educators are also interested in scrutinising the learning environment for its cognitive effects on individuals and on whether this context is useful for the subtle introduction of scientific ideas at an early age.

Children construct knowledge
In this section, I extract data from children's oral and written statements to better access their views. Final conversations with groups were very helpful as children tried to make it clear to me how they constructed their learning and what meaning they took from the learning environment. I discuss in turn, knowledge about shadows, (prior views, views expressed during the unit, and views expressed in final group conversations) how I probed children's thinking about shadow formation and about light traveling, and children's comments on the learning environment and on their own learning

Knowledge about shadows For children's prior views and their changing views throughout the unit, data comes mainly from audio taped children's conversations within groups, conversations which were not conducted in the presence of adults. In this way, I have avoided violating normal conversational rules, a methodological trap which has been identified in some structured interview situations involving research with young children (Siegal, 1991). An additional advantage of this method is that children's understandings and theorisings emerged in response to unexpected stimuli and revealed tacit knowledge which I had not planned to explore. In more deliberate attempts to access children's views using conversations in class about their activities and drawings and for final group conversations, I have tried to avoid breaking normal conversational rules.

Prior views Similarly to children interviewed by Piaget, (1932/70), the majority of Year 2 and some Year 3 children stated some combination of the following: that the shadow was something produced by the object itself, that it could reside in the object, came out when a person walks, was made by a person at night, but was not seen because it was night. Children commented that its shape resembled the object, thought of it as being a substance, reified it, and attributed a vague role to the sun shining in its formation. Some thought that light drives the shadow from the object or that the shadow is attracted by darkness and repelled by light. Some statements made by children exemplify how they expressed these views.

Vicky	A shadow's just a shadow - I don't know how to explain it - it doesn't have blood and bones - it's just this sort of thing.
Vanessa	Um well I know that shadows always come against the sun.
Mary	Why do they come against the sun?
Vanessa	Because the sun is so hot and there's so much sun on the side which the sun is, that there's no room for the shadow where the sun is - there's more room and it's much easier for them to be where the sun is not.
Matt	My shadow is formed by sun shining my way.
Dick	I know when you're walking, when you're walking, when the sun's out or when the clouds are out, when you're walking your shadow follows you along and never gets off you. It will come in to you (when) put in the dark um and that's all I know.

A minority of children expressed a view, which tended to be more scientific, from the beginning.

Andrew (Year 2)	I think my shadow is formed by my body because the sun can't go through your body. If it could you wouldn't have a shadow. A shadow is like a mirror image.

Micky (Year 3))If you're standing on a sunny day it's like the sun is going down creating all the brightness and then your body blocks it off and creates a dark patch where the sun has been blocked off and since your body is blocking it, it forms the shape of yourself.

I asked Micky (a quiet, reticent boy) on the following day, a series of questions about how he had arrived at his view. He replied he had not read about shadows, his parents had not told him and that this was just what he thought. Micky's teacher was initially surprised by his views, but on reflection, thought that he was a clever boy, but that so far, he had not shown his ability in class, or in examinations.

Adding to views throughout the unit Some children articulated ideas spontaneously outside, without any need for direct questioning on the part of the teacher, and this helps to add rigor to my research methodology of recording natural conversation among children, as a way of accessing their views. For example, I did not intend asking children for their views about the role of clouds in the disappearance of shadows, but some comments came outside, as reported already, and inside, on the following day.

Robert The sun forms a shadow with the light of the sun.
Dick But not all the time in the light - see yesterday, I were in the light and the sun was covered by, um, and there was still light and the sun was covered by the clouds.

I consider Dick's comment to be thoughtful and very scientific as it corrects Robert's generalisation, by reminding him that they were outside, in the light, but that there were no shadows. It is indicative of the degree of attention children paid to each other's statements. I contrast this with experiences of PEEL teachers, who felt the need to teach secondary children how to listen and respond to each other (Baird & Mitchell, 1987). Here, this came about naturally, after initial modeling of group interactions.

Micky, who had a scientific view of shadow formation at the beginning of the unit, continued to add to his insights, as he explained the differing shadow shapes. He drew a well conceived geometric diagram illustrating how rays from the sun hit a tree creating shade (not reproduced here).

Micky The sun's rays makes light but when you go into it, you block the sun forming a dark patch, like a tree blocks the sun and it is cool under it because the hot sun is out of the way. As you turn around, the sun hits different places because your body changes its shape. Sometimes when you are playing, it turns dark because a cloud passes the sun making a shadow.

Although he is not scientifically correct in his view of "it turning dark" being caused by being in a cloud's shadow, this is impressive theorising from a nine year old boy.

These segments of conversations in small groups of 7 year old boys and girls, and Year 3 Micky's additional theorising about shadows of clouds, exemplify the power and efficacy of this learning environment. Most children willingly and enthusiastically moved towards full participation as inquiring learners in their cooperative groups. As instantiated here through Dick, children listened carefully to statements made by fellow group members and questioned others' implied assumptions as they constructed deepening knowledge, without teacher intervention.

Views one week after the end of the unit During final group interviews, children exclaimed in pleasure at the familiar materials, as though greeting familiar friends, and instantly began to make shadows again and play. In some ways, this reaction was useful - while the group and I talked about what was happening as they made more shadows, children developed additional insights as they discussed alternative explanations of their observations. Some children were far more interested and involved in playing with the materials, than in talking about their final ideas on shadow formation, so within limited time, I could not talk to all children in depth about their views, but it was clear that many (like Don and Patrick below) had developed their thinking.

In reply to my query about their ideas on shadow formation, Patrick replied:

> There's a light going on the shape and the shape covers up all the light so it turns into a black spot.

And in response to my question about whether a shadow would still be present when there is no light at all, Don, after reconsidering his initial answer of "yes", said:

> I think it wouldn't, because there's no light to form it.

In some cases, children did not change or develop their views, even when I probed them by using Adrian's scientific view of shadow formation, which he expressed often during the reporting stage. (He took over as reporter for his group when Paul became tongue -tied). As an example, I consider Angie, in Year 3.

Gilda	Angie, do you remember Adrian saying that he thought the light came on to the object and hit the object?
Angie	Yeah.
Gilda	And the object blocked the light, and the shadow was at the back where the light couldn't get through.
Angie	Yes.
Gilda	What do you think of that idea?
Angie	Well I think that was true because the light would hit you, but it can't, it can't like when the shadow's in you, it can't show the shadow in your body.

Angie seems initially to agree, then reconsiders. Her initial conception of the shadow residing inside her has not been challenged and this seemed also to be the case for Vicky, a fellow group member, whose views were expressed in a very animistic way, as she held up a torch to represent the sun.

Vicky	It happens because it wants, the sun, this is the sun, and it goes around the earth and this is my finger and it wants to and it sort of like goes to through you, and that's another you, cos it doesn't like yourself and it wants another one. In other words, it doesn't like you and it wants another you.

In this explanation, Vicky treated the sun as something alive and powerful, with its own motive for forming shadows - the sun is trying to make a different version of a person because it does not like the first version.

One of my purposes in developing this model of learning was to provide opportunities for young learners to engage in intellectual discussion about their ideas, by their participation in inquiry, but I did not set out to deliberately effect conceptual change. Watts (1985) has made recommendations for teachers who do wish to effect conceptual change and if teachers so desire, some of these recommendations could be trialed within this learning environment if there were no time constraints. In some final conversations with children, in attempting to probe their reasoning, I did offer challenges to children's thinking, so that consequences of holding two contradictory ideas at the same time were made explicit.

Probing children's thinking According to Piaget's stage theory, in his third stage, children (of average age 8) can predict the orientation of shadows, indicating an understanding of a role for light in shadow formation and can also predict where the sun is to be found, given the shadow position. Significantly, in this stage, children still believe objects produce shadows at night. In his discussion of this stage, Piaget points out that although the prediction has shifted to a higher stage level, the explanation remains lodged at an earlier stage (Piaget, 1970). (I conjecture that children's seeming reluctance to abandon their transitional views about shadow formation could be linked to their very early cognition of object permanence).

Using this information, I found that one useful probe of children's scientific understanding of shadow formation was to build questions around children's possible beliefs that objects still have shadows at night. One obstacle to be overcome in asking this question, is that I found that many children resisted the idea that there could be a complete absence of light at night, as this was directly contrary to their own experience. Part of my final conversation with Vanessa exemplifies this.

Gilda	You're in your bed at night. There's no light in the room, OK, no light at all, so its completely dark. Do you still have a shadow?
Vanessa	No.
Gilda	No? Not at all? *(Is this breaking conversational rules?)*
Vanessa	A very faint one.
Gilda	A very faint one?
Vanessa	If it's pitch black then there's nothing at all.
Gilda	No. Would the shadow still be there though?
Vanessa	Yes.
Gilda	Why do you think that Vanessa?
Vanessa	Because its very hard to be pitch black.
Gilda	I see.
Vanessa	And at night I stay awake until two o'clock in the morning and I never see a time where there's no shadows of teddy bears.
Gilda	But just supposing it was absolutely pitch black. Is it possible for you not to have a shadow, if its absolutely pitch black?
Vanessa	No.
Gilda	No, why do you think that one?
Vanessa	<u>Cos the shadow's there and you just can't see it</u>.
Gilda	Can you tell me why you think the shadow's there and you can't see it, Vanessa.
Vanessa	Because its dark and you can't see it.
Gilda	Oh I see.
Vanessa	You can't see in the dark.
Gilda	But you told me before that the sun had to be, or some light had to be there to make a shadow.
Vanessa	Yes, there's just a winsy, tinsy, bit, little bit of light come out.
Gilda	Yes, but I've just said, say there's no light.
Vanessa	Oh.
Gilda	And you've said the shadow's still there, but you can't see it.
Vanessa	mm?
Gilda	Does that seem strange?
Vanessa	mm, yes.

During this conversation, Vanessa spoke light heartedly, conversing with me, while she gaily played with torches and cellophane, constructing an imaginary story about coloured lights falling on the little animal on the table. Her mind was more on her play than on her conversation with me, but her tone of voice conveyed the non problematic nature of my questions. To her, it was perfectly logical that a shadow could still be there in the dark, unseen, because light was needed to see the shadow. Although she briefly thought about the consequences of holding contradictory views of light being needed to form shadows and shadows being present in the dark, without light, she was not engaged by the question.

In contrast, Dick (who did not hold a scientific view early) completely rejected the idea that there could be a shadow in pitch blackness, as for him, the necessity of having light to form it, was an over-riding factor and he argued with his friend Ross, as the subject was being discussed.

Gilda	So you would say then that if you were in your dark room at night without any lights on and all the blinds down,
Andrew	Yes.
Gilda	Would you say you had a shadow?
Dick	No way.
Andrew	No. Only in the light.
Ross	There might be a shadow there, but you couldn't see a shadow.
Gilda	I see.
Andrew	When I walk to the door of my room, there is a shadow on me because Mum always leaves the bathroom light on.
Gilda	But I've said there's no lights here. Ross said something interesting. He thinks there might be a shadow there but you can't see it.
Ross	Yeah.
Gilda	Is that what you think Ross?
Dick	No there isn't a shadow there.
Gilda	There isn't...
Dick	And you can't even see it.
Gilda	Why do you think that?
Dick	Because there's no light. You need a light to form a shadow.
[Gilda	What do you reckon about that Ross?
[Ross	Not all the time.
Gilda	Not all the time?
Dick	Yes all the time.
Gilda	Why don't you think that Ross?
Dick	Yeah (*said a little challengingly*). All the time you need light to form shadows.
Ross	Well not all times.
Gilda	No?
Dick	Well what are you saying?

This example highlights the shadows context as one which young children can, and do enter, with intellectual enthusiasm. It also highlights one advantage of conducting my final interviews with a group, instead of with individuals, as Dick probed Ross's views without my needing to break conversational rules.

I noticed that some children were prepared to participate in an exchange of views more fully than others, but perhaps disturbingly, a couple of youngsters resisted any implicit questioning of their views, claiming that they "knew all about shadows". Perhaps this is an early indication of children who are beginning to close off options for later science learning.

<u>Summary of useful probes to check specific understandings</u> I used other useful probes (both direct and indirect) of children's understanding of shadows and whether light travels, and for convenience, group these probes as follows.

Asking for predictions about:

1 position of shadow prior to turning on a torch.
2 position of shadow if object is turned through 180 degrees to face the other way.
3 size of shadow if position of torch is changed.
4 position of shadow if torch angle is changed.

Asking questions to distinguish between:

5 background and shadow when coloured light is shone at an object
6 background and shadow when white light is shone at an object constructed partly of opaque material and partly of coloured cellophane.

Finding out if:

7 children can state what happens to the light when it "shines" on an object.

8 children think that shadows are still present in complete darkness.
9 children think there is light between the torch and an object.
10 children think light is moving between the torch and an object.

Once I had clarified, for question 10, that I did not mean that the source of light was moving, some children with a scientific view of shadow formation were adamant that the light itself must be moving. This is exemplified in an extract from the final interview with Dick, Ross and Andrew.

Gilda	I don't mean the sun itself moving, I mean actually the light.
Dick	The light - the torch can move.
Gilda	Not the torch, I'm talking about the light coming out of the torch. Is that moving at all?
Dick	It is.
Andrew	Yes it moves. It moves from there to there like that. *(He gestured with his hand from the torch to the toy).*
Gilda	Why do you think that?
Andrew	But it does it faster, it does it faster than I'd say, um, half or quarter of a second.
Gilda	Wow, really fast eh.

This is a more sophisticated understanding of light traveling in space than has previously been reported for this age group (Guesne, 1985) and indicates that the context of shadows can be used to embed this powerful concept at an early age.

I turn now to some children's additional cognitive learning. Some of this was metacognitive, in that they recalled prior views of shadow formation and ways in which they changed their views; some learning was very perceptive awareness and construction of my purposes in creating the learning environment.

Children's comments on the learning environment and on their own learning In our final conversations, some children told me casually how they regarded learning science in my sessions. I quote Ellie, who generalised her statement to include her understanding of what others thought. Robert, like a few other children, was metacognitively aware of his learning. He also articulated a major design feature of the learning environment and his construction of my purpose.

Ellie's passing comment, made during the final interview, about how she and other class members saw these science lessons, provides additional support for my claim that a learning environment, without external rewards, is satisfying and meaningful to children in ways that differ from their expectations of formal schooling.

Gilda	Did you like working in a group?
Ellie	Yes. Everyone liked it. They could come in.
Gilda	Did they? Why did they like it?
Ellie	They liked to stop work.
Gilda	Don't you think this is work?
Ellie	They didn't think it was.

Ellie's comment "they could come in" probably refers to children happily escorting me and my equipment into their classroom, prior to the bell signaling the end of lunch. More significantly, Ellie's claim that many children did not view these lessons as work provides support for my learning environment, as one which is intellectually subtle, inclusive and enjoyable.

As soon as Adrian, Robert (both Year 3) and Paul (Year 2) came into the resource room to talk to me, Robert began straight away to tell me how the multiple shadows of a toy camel, lit from one side by a bank of windows, were being formed. I recollected that Adrian had expounded a scientific idea of shadow formation from about the third lesson and suspected that Robert's scientific view had been helped by what Adrian had consistently maintained in his small group setting and three times, in front of the class, as reporter.

Gilda	Now I noticed that when you were talking in your groups there, that you knew a lot of that before you started.
Robert	I did?
Gilda	Do you think you did? You don't think you did?
Adrian	Yes.
Gilda	Or no? What do you think? Robert, do you think you did?
Robert	I didn't.
Gilda	I'm very interested in that. Why do you know it so well now?
Robert	Well its just been experimenting. Because when I were sitting down trying to think of ideas how shadows work, I just said "through the sun" and then I just sort of thought up an idea.
Gilda	What do you think gave you those ideas the best? Did you work them out yourself?
Robert	Yeah, well I just said "through the sun" and I suddenly just thought and I was just putting my hand out and stuff and sort of trying to work out why and how and if there's much sun and stuff and so I just worked (it) out and I did.

Robert is certain of how his knowledge came about, (through putting his hand out in front of a light source) and does not mention his friend's often repeated scientific explanation. I interpret this as an example of construction of knowledge, supported by this learning environment, as Robert's inspiration and inclinations to experiment were derived from my shadows context as his problem source and perhaps (unrecognised by himself, Adrian's explanations). Later in the conversation, he seems to recognise for the first time that his friend's explanation of shadow formation is the same as his own.

Adrian	Well, I've still got the same theory.
Gilda	Yes?
Adrian	Its light shining onto something, that's - it has to be a three D shape. And it can't pass through the camel, so it won't go through it, so it's.. it'd be like there was no sun at all. *(In the region of the shadow).*
Robert	That's the same as me, Adrian.

Adrian did not comment on Robert's last statement. This seems to be another form of social knowledge about friendship. In allowing Robert to own his personal theory, he adds to Robert's self esteem and their friendship remains strong. This is an entirely different situation to that reported earlier, where Martin, without any ties of friendship or loyalty to Katy, was certain she had copied his group's idea, and most saliently, to his vehemently expressed opposition, as I will shortly report, to Paul's copying role in this group.

I was interested in children's construction of my role in their classroom and I asked about this in final interviews. Many children simply answered that I was teaching them about shadows, and when asked if I had actually given them information, they invariably revised their answers to state that they had found out a lot for themselves. Robert went further.

Gilda	Tell me what you thought that I've been doing here all this time I've been here. What have been your impressions? What's going on?
Robert	You're trying to give us a bit more knowledge about um, I could ask all these questions, things like "Hey, what's that?" when I grow up and stuff, and I can just, and now you've taught us, we know where they've come from.

Earlier as reported above, Robert explicitly recounted how he worked out for himself how shadows were formed. I therefore feel that this statement means that he is metacognitively aware of the process of learning by inquiry, a critical aspect of the learning environment and that this will be useful to him as an adult. I interpret the final part of his sentence, "and now you've taught us...", as meaning "now you have facilitated our learning and we have worked out for ourselves how shadows are formed".

Through complex inter-relationships between inquirers, knowledge generated and context, as shown in many conversations which occurred, most children were constructing their identities as successful participants in this learning environment. There were only a few obvious counter examples. The case of Katy has been briefly discussed. In the following section on identity construction, I first turn to another example of a child who seemed to participate in this environment in a way which did not serve him well, as a copier of others' ideas, and as before, I interrogate the environment itself, for its failure to offer him the support he needed. My final finding will again examine the environment and its role in identity construction, this time for its maintenance of its inclusively designed nature.

Construction of identity

The case of the child who copied In a more disturbing part of the conversation with Robert, Adrian and Paul, Adrian unexpectedly attacked Paul's lack of participation in their joint effort. I had asked if there was any part of what they had done that they did not like and Adrian promptly replied: "Paul." He then elaborated, cutting across my remark "That's unkind."

Adrian	He didn't know anything. He really copied off all our things - he didn't give us any ideas.
Gilda	But is that - is there anything wrong with that?

In showing his frustration with Paul's copying, Adrian's ready acceptance, as discussed above, of Robert's adoption of a view which he would regard as his own, is all the more remarkable.

Further discussion, in which I tried to point out that Paul was in Year 2 and they were in Year 3, and that one purpose was for children to help each other, was met with the rational argument that other Year 2 children had lots of ideas. Analysis of their taped conversations confirmed their perceptions - Paul rarely contributed, even if asked something directly. If he did answer, he repeated what one of them had already mentioned. It is difficult to know how much to attribute to Paul's only having been in the country one year, but it is hard to discount this. It is also possible that Paul did not understand the subtlety of the cooperative demands of the task and the unwritten penalties of not participating more equally in this setting. My failure to pre-define or discuss some individual's needs to participate more peripherally in a small group setting could have exacerbated Paul's difficulties.

During any attempt to talk to Paul, I was unable to encourage him to give more than monosyllabic answers and hence his point of view is only inferred in this discussion. According to his teacher, he was able to understand English well. Adrian and Robert were not the only ones to express resentment of Paul to me. While I was observing the class prior to starting lessons, other children told me that Paul was naughty and did not obey the teacher's rules. At this time, he had a maths game from the shelf which he was not supposed to be using. I also observed Paul's unwillingness to obey rules. Children were taking it in turns to use the video camera during the last few lessons (I collected some very jumpy footage here) and Paul, after having had his turn, tried on a couple of occasions to ta..e the camera from other children.

Although signs of Paul's inability to grow healthily in my learning environment were apparent early, I did not recognise, until the final interview situation, how deeply I should have been concerned about him. In common with many other teachers, (see Mac an Ghaill's description of his methodology of his ethnographic study of black students (1991) in which he describes how he changed his theoretical perspective in identifying racism, rather than the students themselves, as a cause of their schooling problems), I tended, during my lessons, to locate Paul's problems within himself, as an individual, instead of within my learning environment, the school system and the wider society.

Paul's case illustrates that even small cooperative groups may reinforce a negative picture of self, unless a different perspective on the cause of individual's actions is adopted, and unless there is a change in classroom culture that validates some actions that teachers and children have assumed to be illegitimate - in this case, copying.

Re-examining our assumptions about copying would seem timely. As teachers, we endorse it strongly, when we wish children to learn by our example - in this study by the modeling of group discussion, but it is equally strongly condemned, when children attempt to copy others, by both teachers and children themselves. In a classroom culture which adopted wider definitions of learning, copying could easily be presented as acceptable under certain circumstances. Explicit discussion between class teacher and class could assist children to recognise that newcomers have a legitimate peripheral role, as they learn by observing old-timers. The related point, that newcomers have different needs and rates of learning, so that exact specifications should be avoided, will also need to be made.

In a very important sense, recognition of differences leads to the final finding in this section, whether and how children transformed the inclusive nature of their learning environment.

Identity and inclusion I have already indicated that my shadows context was chosen as one inclusive of children's previous experiences and backgrounds. The materials in equipment boxes supplied to each group for experimentation on shadow making were also chosen for inclusion, by using a variety of familiar objects from which children could select according to their appeal: large and small torches, toy animals, small attractive china ornaments, smurfs, coloured pipe cleaners, coloured cellophane paper, coloured tissue paper, aluminium pie plates with holes, plastic bags. Spontaneous comments as children explored their boxes, and my videos of the variety of objects used and constructed for use during inquiry into shadow formation validated my choice of materials as having appeal to most children.

My previous analysis of Paul's peripheral participation has made me more sensitive to ways in which my settings may not be inclusive of children new to a classroom or to a country, in spite of careful attempts to place such children with seemingly mature others. Paul's small group was transformed from one designed to support his learning, to one in which his social growth was disadvantaged. Only by reframing the problem as arising from the environment, rather than from the individual, I believe, will teachers' reflections and analyses of similar situations be useful to a child's eventual internalisation of self as someone valued and liked.

Observations in secondary science classrooms (Kelly, 1987) draw attention to ways in which boys' actions can construct science as masculine. I did not observe gendered use of the whole class setting or reporting setting, but some children participated in their small group settings to transform them according to gendered societal norms.

Three groups of boys used the shadows context outside to reinforce masculinity: in one case, by examination of muscles of shadows; in two other groups by spontaneously playing "killing shadows" games. The conversation of one group of three boys indicates how readily the popular culture can intrude into children's inquiry.

John	Oh, there's a shadow.
Mark	Lets play the killing game.
Andy	You've got to try to kill other peoples' shadows.
John	I'm trying to kill my head.
Mark	I can kill my head.

In work with Kindergarten at this school, I also observed spontaneously violent action-games of young boys as they kicked their shadows against a wall (Segal & Cosgrove, 1993); girls did not play games of this kind in either class.

Materials supplied inside appealed to boys and girls. Femininity was reinforced by remarks such as "Oh, pretty!", while the same materials were used by boys to construct "weird monsters".

My evidence suggests that although my learning environment may be considered gender inclusive in that it did not alienate boys or girls as a group, some children appropriated their small group to construct their identity and gender to conform to societal expectations.

These social issues raise pedagogical questions for teachers of primary science: Is there a place in the primary science curriculum to raise issues of social exclusion, racial prejudice or gender construction with young children when observations are made in the context of science activities? How might this best be done to support young children, rather than confuse them?

My research raises ethical questions here too. If teachers plan to carry out action research in their classrooms and do tape conversations which they wish to challenge, should they?

SUMMARY AND CONCLUSIONS

This first experience with cooperative group work of the class gives insight into ways in which young children handle preliminary group-spirit-building tasks and assigned roles after assistance by modeling.

Most young children were prepared to risk stating their views in their small group and to the class. Some children were able to participate fully in my settings, co-constructing knowledge, modes of scientific inquiry, ways of relating to each other and to the context, with most children supporting each other socially within our small group setting. I consider this is a significant finding in the context of young children's education, especially as the class was inexperienced in this type of activity.

Initially, from a teaching and learning point of view, I perceived advantages in the reporting setting. I saw this setting as a means of sharing information located in some groups but not in others, thereby seeding inquiry in other groups; I assumed that the prospect of reporting to the class offered prior encouragement to children within their small groups to focus on their observations and interpretations; I liked the opportunities the setting offered to each children, to practice addressing their peers. In practice, I found that the transmissive nature of this setting outweighed my preconceived advantages, as many participants were powerlessly constructed as listeners. I recommend that teachers and children jointly discuss problems of settings as they arise and assume joint responsibility for everyone's welfare within settings.

I was able to trace the learning of some children as they identified prior views about shadows in small groups, listened to each others' views and modified their own views after engaging in activities. This was accomplished without didactic teaching, without purposefully transmitting information to small groups and without rewards or assessment structures. Absence of expectation of extrinsic reward may be a key construct of this learning environment. In a few cases, interestingly, children adopted a metacognitive perspective and were able to report on the ways in which their views developed and changed. Significantly, children did not ask me which views were correct or incorrect, preferring to rely on results of their own investigations.

In the final conversations with small groups, I used some conversational probes to access fine details of children's ideas about shadow formation. I hypothesise in this connection that children's seeming reluctance to abandon their transitional views about shadow formation could be linked to their very early cognition of object permanence.

My original choice of shadows was dictated by the embedding of the central idea that light travels, within this context. I raised this notion with some children in final interviews, but they immediately focused on light, as meaning source or effect. Children whose views of shadow formation matched scientific ideas seemed to be able to conceive as light as an entity that travels in space. Other researchers have not reported finding this particular conceptual understanding when interviewing young children (Guesne, 1985).

Similarities between Lave's (1992) community of practice and my classroom settings may explain children's high level of motivation. My settings, like those of authentic practice, lack an individualistic perspective with its emphasis on competition, formal testing and a predefined powerlessness of participants: groups can construct and negotiate their own interpretation of the task. Intellectual conversation within small groups and the pleasurable seriousness with which most children operated contrasted with their affirmation that they were not doing work. With no marks or explicit criteria for success or censure; the task appears to be more authentic. Under children's control, it can be molded according to children's wishes.

My learning environment was designed as inclusive. During the unit and in final group conversations, many children mentioned their play at home or outside school, with torches. Their experiences with shadows connecting school to the outside world, support shadows as an inclusive context for school learning as participating and gaining identity. Some children's transformation of the environment in accordance with their conceptions of gendered identities, raises pedagogical issues for teachers. I would support judicious deconstruction of gendered/classist and racist behaviours through discussion, as part of an inclusive primary science curriculum, but recognise further research is needed in this area.

I have discussed examples of problems which led children to participate in this environment, in ways that did not always serve their own best interests. While I advocate that children should be encouraged to take personal and social responsibility for their actions, I also propose that teachers, through implicit and explicit validation of observing and copying as forms of learning, should assist newcomers and shy children, by authenticating copying as legitimate peripheral participation in the classroom learning community. A theoretical interpretation of learning which validates children as legitimate peripheral participators could incorporate multiple views of permissible ways of learning. This would seem to offer more promise for creating mentally healthy and productive citizens than a framework which situates all the blame on individuals for their failures.

EDUCATIONAL IMPLICATIONS

I have assumed that children should be encouraged to articulate their views of physical and biological phenomena early in schooling, before these views become inflexible. My assumption is embedded in a holistic view of learning and teaching, which seeks to create a learning environment which is relational to children, teachers and subject to be learned. In finding acceptable ways in which all participants can move towards full participation in their learning environments, I hold that the school system and units within in it, should confront societal problems within the classroom contexts in which they arise, as part of the school curriculum. I see the role of a school science curriculum as transformative, not as reproductive of societal problems in miniature. The learning environment I have investigated in this study has the potential to fulfill this role.

If teachers encourage young children to question, rather than passively accept, their intuitive views, to query information presented to them as facts before accepting it, to develop personal satisfaction and self-esteem from experiential learning in science, to take responsibility within their learning environment to solve problems which are a property of that environment, then as children develop, they could closely examine the history of construction of scientific and technological knowledge, its values and its ethics. This kind of personal scrutiny and the satisfaction it brings could be part of the complex array of factors which underpin later successful learning and positive attitudes to science and to society. This, in turn, could attract committed and ethical students to scientific careers and to questioning societal norms which define some groups as without power or hope.

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