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Deconstructing Learning in Science — Young Children's Responses to a Classroom Sequence on Evaporation

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Abstract

Five year old children's ideas were tracked by a range of means during and subsequent to a classroom sequence on evaporation. They held a range of conceptions which changed in complex ways across context and time. These could only be made sense of by moving outside traditional conceptual change interpretations to include broader notions of appropriation of language as a cultural tool, of personal and social narrative responses to features of the phenomena and the classroom setting, and the nature of science explanations. The findings are used to explore the relationship between social and individual perspectives on learning, and to question some assumptions underlying conceptual change research.

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Objectives of the Study

The study concerned the dimensions of five year old children's conceptual responses to a teaching sequence on evaporation. It explored:

1. the range of ideas children have concerning evaporation phenomena, and the consistency with which they apply these ideas to different phenomena, across a six month time span;
2. the ways in which children construct meaning from different aspects of the pedagogic setting; and
3. the factors that position children within classroom discourses, and impact on their science learning.

This study forms part of a larger research program which is tracing the conceptual development in science of individual children, across a number of years.

Theoretical Underpinnings

Within the general framework of research into students' science conceptions, there have been many studies which chart the differences in conceptions held by different age students. Such studies tend to be firmly based in a cognitive model, perhaps arising from their links with the earlier Piagetian program which emphasised developmental cognitive features of learning (Driver & Easley, 1978). These studies view learning in terms of a sequential development of increasingly sophisticated conceptualisations within a given domain (Driver, Leach, Scott, & Wood-Robinson, 1994). The purpose of such research has been to uncover the critical aspects of students' ideas that underlie major conceptual change, and the hope is that these findings can help frame advice to curriculum developers as to the appropriate sequencing of content, and to alert teachers to the critical features of student conceptions of phenomena that need to be

negotiated in classroom learning. There have been a number of writers calling, however, for the inclusion of broader perspectives than the purely conceptual, on student science conceptions. Still within the cognitive domain, there have been calls for instance to include epistemological dimensions of learning in accounts of conceptual change. Driver and her colleagues (1994) identify these, as well as reasoning strategies, as factors underlying conceptual progression. Duschl and Gitomer (1991) and Driver, Leach, Millar, and Scott (1996) have argued for the importance of students' views on knowledge production and the nature of science. We have also charted various aspects of student epistemologies and their relationship to conceptual learning, in a number of content areas (Tytler, 1994, 1998b, 1999, 2000).

Strike and Posner (1992) move further beyond the strictly conceptual in arguing for the importance of students' conceptual ecology in framing the change process. The term 'conceptual ecology' encompasses students' broader beliefs and dispositions. Other writers have also emphasised the importance of affective factors in the process. Pintrich, Marx and Boyle (1993) describe a range of classroom contextual, motivational and cognitive factors that impact on conceptual change. Thus, there is a growing body of opinion that, in order to understand the nature of science learning in classrooms, and provide advice for the effective teaching of science, we must draw on a number of dimensions beyond the strictly conceptual. Such views, however, still tend to frame these dimensions in terms of individual epistemological, dispositional or motivational factors. Conceptual learning is seen as occurring in individual students' heads, governed to some extent by what happens in individual students' hearts. Within this mainstream conceptual change literature, social and cultural features of classroom settings have been granted subsidiary role status only, when interpreting individual learning and conceptual progression.

Separate from this conceptual change literature focused on individuals, there exists a rich literature, deriving from the work of Vygotsky, arguing that learning should be seen primarily as a cultural phenomenon, involving children appropriating discursive and other tools which give them access to shared ways of seeing the world of phenomena. Socio-cultural and situated cognition studies focus on the way particular pedagogic settings influence the joint construction of meaning (e.g., Driver, Asoko, Leach, Mortimer, & Scott, 1994; Hennessy & Murphy, 1999). Researchers trying to establish conceptual trajectories need to be aware of the possibilities for learning that are available in particular settings and the potential for individuals to participate in these in order to interpret learning outcomes validly. Both perspectives — the individual and the social / situated — offer powerful insights into children's learning. The bringing together of these perspectives has been advocated recently by educational theorists such as Cobb (1994), Bruner (1996) and Sfard (1998), but has not yet been taken forward empirically. This study offers a step in this direction, by focusing on children's responses to a range of features, conceptual and social, of the pedagogic setting.

Background to the Study

Children's Ideas about Evaporation

The particular vehicle for this study is a classroom sequence concerning evaporation, taught to children in their first few months of primary school. There exists already a literature on children's ideas about evaporation, most of which would indicate that the scientific concept is not available to children of age five. For instance, Bar and Travis (1991) and Bar and Galili (1994) studied the understandings of evaporation of children of different ages, and in different contexts, and found that until the age of approximately seven, children tend to consider that water simply disappears. At seven years of age they begin to reason that the water must have gone somewhere, and shift to a 'soaking in' notion. It is not until about the age of nine that children consider water being transferred upwards, to the sky or ceiling or clouds. This difficulty with the idea of water changing to an imperceptible form can be understood at a broader level from a Piagetian perspective, by asserting that five year old children are at a pre operational stage and would be limited to thinking in concrete, context specific terms, that would preclude an ability to reason about where water might go once it is no longer visible, or countenance water in an imperceptible state. Further reviews of the literature on students' views on evaporation can be found in Driver et al. (1994), Garnett, Garnett and Hackling (1995) and Tytler (2000).

Notwithstanding these cautions, we had reason to explore further the possibility that there may be more to children's understandings about evaporation than implied by these studies. Firstly, Piagetian ideas have been questioned for some years, in terms of their focus on development of logical reasoning to the exclusion of consideration of students' often quite coherent and complex reasoning about particular phenomena (Driver & Easley, 1978; Ramadas & Driver, 1991), their assertion that the ability to learn is strictly determined by developmental constraints (Carey, 1986), and for the 'dumbing down' effect Piagetian stage theory has been said to have on the ideas recommended in curricula for children to engage with (see, for instance, Metz, 1997). A study by Skamp (1995) of a constructivist teaching sequence on evaporation for Grade 1 children claimed success in establishing the idea of water evaporating into the air, across more than one context.

Prior Research by the Authors

In a previous research project the authors had explored the ideas of Year 1 children about evaporation and condensation (Tytler, 2000) and found their thinking to be in advance of those suggested by previous studies. A categorisation system which describes children's ideas was developed from this previous study, and is shown in Table 1, with the code and description for each category. It will be used as part of the present study.

In a follow up study (Tytler, 1997) in which evaporation sequences were run in the same school with different age groups, two findings seemed clear. Firstly, upper primary school children were much better able to engage with reasoned investigations into these phenomena than either preparatory year (five year old) or year 3 children. Secondly, while the preparatory children were able to talk about interchange with the air as an explanation for both evaporation and condensation phenomena, in a probe administered six months later their ideas ranged across all the categories for evaporation, and had reverted to C1 (see Table 1), "It's just like that," almost universally for condensation. By contrast, grade 6 children had almost uniformly mastered the scientific conception of these events. While this finding is not inconsistent with either Piagetian views or the previous research into student conceptions, we were intrigued by the volatility of these young 5 year old children's conceptions, and the fact that they seemed to have access to more sophisticated ideas than one might have expected, even if they did not apply them consistently. The water cycle has achieved an almost iconic status, being one of the most often taught science topics in primary school, often dealt with in the early years. It is an abiding image in the adult cultural lexicon. Given its strong cultural presence, and for all the reasons above, when the opportunity arose to look more closely at children's conceptual engagement with phenomena over a period of time, evaporation was one conceptual area we were keen to try. This was the genesis of the classroom sequence described below.

The aim of the study is twofold; to attempt to unravel the key problems these children are grappling with and the resources they bring to bear on this, and secondly to explore how these children's view of themselves in relation to classroom processes interacts with their conceptual learning.

This paper analyses events over these children's first year of school. At the time of writing, the children are in their third year, and their understandings of evaporation are continuing to be charted. This longitudinal aspect of their learning will be reported on separately.

Research Design and Procedure

The wider research program employs a case study methodology, tracing conceptual change in fifteen individual children over at least two years. These children were selected, in consultation with the teacher, to be representative of the class as a whole. The approach is interpretive and qualitative, with data collected from recorded class discussions, interviews and transcribed probes being analysed to explore children's changing conceptions and epistemological frameworks, and also the way their responses are framed within the classroom dynamic. The subjects of the research are children from a suburban primary school, in their first year (from age five).

The class was visited extensively over a five week periods at the beginning of the year. During this time the class participated in a variety of activities exploring their conceptions of evaporation phenomena. Details of the topics and activities were developed in consultation with

Table 1
Categorising Children's Conceptions of Evaporation

Code	Description
C1 It's just like that	Refers to responses that explain on the basis that this always happens, like "the puddle dried up in the sun" or "the alcohol disappeared." The category includes simple causal statements such as moisture appearing "because of the ice," or descriptions like "bubbles come up and steam comes up."
C2 Associations	Refers to associative thinking that is offered as an explanation in its own right; for example a reference to water "dissolving" into clothes, or the water "drinking up into the sun," or a puddle drying up because of a clash between the hot sun and cold water.
C3 Displacement – local	The liquid changes position, but not form, as in "dripping to the ground," "going underground," or "soaking into" surfaces.
C4 Displacement – water cycle	Refers to responses that mention the water going to the sky, or the sun, or the clouds. Occasionally children extended this essentially displacement image to water "rising to the ceiling."
C5 Air	Water goes into or comes from the air or atmosphere. The critical difference that distinguishes this conception from the water cycle conception is the implication that water goes 'into' air as a local entity, rather than up to the air or sky.
C6 Change in form	Water changes to or from another form, which could be perceptible such as steam or fog or moisture, or imperceptible, such as vapour or gas.

the teacher. Each sequence was planned to include activities and probes that focus on children's understandings of substantive science concepts, and included elements of investigative science.

During the sequence on evaporation the classroom discussion was recorded and transcribed, and children's drawings representing their responses to a variety of activities were collected, and associated explanatory statements transcribed. The fifteen children were interviewed before and after the topic sequence about their explanations of the various tasks and their perceptions of the topics in general. The broad understandings and contextual variations of their explanations were at issue in this interview, allowing insight into individual conceptual trajectories. A number of other aspects of their thinking were explored in the interviews, including their responses to investigations and challenges concerning evidence. The interviews were conducted in the style of a Piagetian clinical interview, rather like a conversation but with particular agendas followed for each task. The children were encouraged to explore, and to express ideas in their own language, but there were sections of the interview in which they were asked to respond to challenges presented by the interviewer.

The Evaporation Activity and Probe Sequence

The aspects of the interviews, probes, and activity sequence relevant to evaporation was as follows:

Mid-March: A probe involving changes to matter activities (evaporation, condensation, dissolving) was run in groups. The group discussion was recorded and children produced a drawing and a written (transcribed) explanation of each activity.

Late March: A four lesson evaporation / condensation sequence was conducted, designed collaboratively by the teacher and researchers.

The lessons involved the following activities:

1. Puddles were made in the schoolground, one in the sun and one in the shade. Their 'disappearance' was charted and discussed.
2. Salt was mixed with water, then heated in the classroom in an electric frypan. The water evaporated leaving salt behind.
3. Puddles were made in plates and left in various positions in the classroom (by a window, in the fridge, with gladwrap over one ...). The different rates of disappearance were noted.

4. Samples of cloth were immersed in water and hung to dry in different locations (in the sun, the fridge, wrapped in plastic, in front of a fan....).
5. Bottles of cold, coloured water were removed from the fridge and placed in the classroom. Children watched as condensation appeared.

What is happening? What causes the fog?

The teacher taught the sequence according to her own principles. In the class and group discussions accompanying the activities, she encouraged and challenged children's ideas, explicitly privileged views that were thoughtful and/or consistent with science understandings, and attempted by questioning and emphasis to move children towards an acceptable interpretation. While this was an overt teaching sequence, she did not push for closure on ideas to the point of enforcing a particular set of words to describe the phenomena, but over the time there were many references to water going into the air, out of the window, or up into clouds, which she drew attention to with repetition and encouragement ("that's a really interesting idea," "well done" etc.).

Early April: The fifteen children were interviewed about what they understood about the purpose of the sequence and the activities;
September: The children were again interviewed about the sequence, using photographs as prompts.

Findings

Analysis of the children's explanations of the various evaporation phenomena, over time, showed a very complex picture from which no sensible trends could be discerned in terms of the conceptual ideas (Table 1) that had proved useful for describing differences between

younger and older children (Tytler, 2000). The first four categories seemed to be essentially accessible to all children, although each child showed preferences. Children used the two most sophisticated categories inconsistently.

Table 2 shows the extent to which children ranged across these categories prior to and during the unit and the two interviews. It is clear that children cannot be said to hold particular conceptual positions with regard to evaporation, as described by these categories. If there is coherence in their ideas, it must be looked for elsewhere.

Table 2
Number of Instances of Use of Different Conceptions, for Each Child

Child	Category					
	C1	C2	C3	C4	C5	C6
Amy	4	1	5	3	-	-
Chad	1	1	3	-	-	-
Ella	4	1	3	2	-	-
Emily	3	2	4	1	2	-
Evelyn	4	1	3	2	1	-
Jamie	-	3	3	6	-	1
Kaye	3	1	6	2	-	1
Larry	1	3	3	-	1	-
Larinda	-	1	5	2	-	-
Miles	1	1	-	4	-	-
Rae	-	1	2	4	-	-
Rosalie	3	2	2	4	-	2
Sonya	1	-	3	1	-	-
Theo	2	1	2	1	-	-
Walter	2	1	8	-	-	-

Note: For description of C1 to C6 see Table 1

Making Sense of Children's Changing Ideas

Sense could only be made of the children's ideas by looking closely at their individual responses for similar phenomena. Their explanations of what was happening were grouped in time sequence (using the NUD*IST software as a sorting device), separately for normal temperature evaporation (puddles, and drying clothes), boiling water, and condensation. The responses to the condensation phenomenon were very different to the evaporation responses and will not be included in this analysis. The analysis will mainly focus on children's views about evaporation at normal temperatures. There was some coherence to the way children explained the different phenomena over time, but no general trend in terms of movement across categories with time. We found that some sense could be made of their shifting ideas using a number of constructs. A first set of these constructs relate to the conceptual aspects of the children's views, such as their view of substance, which is presumed to describe something that exists in an individual child's mind. While these sit within the general tradition of the conceptual change / conceptual progression literature, there are sufficient complexities in these children's changing views to raise questions about the completeness of a view of learning predicated on progression of an individual through a conceptual hierarchy.

The second set of constructs relate to broader aspects of children's ways of knowing; their views of the salience of different aspects of classroom activities, which impact on their science learning. It is with this second set of constructs that we begin to see the difficulty of constructing a sensible view of the learning that occurs in classrooms, if we restrict ourselves to progression in the purely conceptual domain. We will start with the first set of constructs; those relating to children's science conceptions.

Conceptions of Substance

The main task we were asking of these children was to become committed to the notion that water had an ongoing identity through these evaporation phenomena. The question "What has happened to the water" was often met with "it has dried up," occasionally voiced as "it has disappeared." The context in almost all cases, however, made it clear that the children did not really feel the water had ceased to exist, and they accepted the follow up question, "where did the water go?" as sensible, even if they were perplexed as to how to answer it. That they could recognise the sense of the question, however, did not mean that they chose to interpret the phenomena in these terms, and embedding the question in their sense making of evaporation was an important aim of the sequence. For many children the 'drying up' terminology was used in conjunction with other conceptions, such as "When we made the puddle some of it dried up and then goes to the clouds and then the clouds make fog." It would seem, then, that contrary to claims of previous research, these age five children are well able to accept the idea of substance as ongoing, at least in a general sense, even if they do not foreground conservation in their commentaries.

Location and Language

The main problem the children had to solve was to explain where the water had gone. There were two main solutions to this, from the start. Images of water dripping onto or soaking into the ground competed with images of water moving upwards, mainly to the clouds or sun, but also to ceilings, or in a general sense. The main difficulty was that they had neither a concept of air to act as a site for the water to exist, or a clear view of the position of the atmosphere in relation to the sun or to clouds. They responded to these conceptual constraints in a variety of ways, including explicitly maintaining multiple positions.

Children often oscillated between the different displacement conceptions – down, into, and up, sometimes explicitly acknowledging a choice: "I think it just dried into the ground or it just rises up to the sun for rain" (Kaye, 17 September). Children would hold both ideas at the same time, as multiple perspectives (Tytler, 1994, 1998a), and on occasions explicitly voiced this as a characteristic of their thinking. Previous claims in the literature (e.g., Bar & Galili, 1994) that these different displacement conceptions represent different developmental stages, do not seem to be supported by these findings. It is possible, however, that what we are seeing is a conflict between an imposed water cycle view, accessed through adult references, but adopted with minimal understanding, and a more readily accessible view of water dripping, or soaking in.

Children had different degrees of specificity as to the way they envisaged location. Jamie represented precise locations governed by a highly developed visual sense (see below), and other children were very definite in their language about "the water goes ....." Other children, however, used non-specific reference to "other places" where the sun might not be out, as part of the mystery of the water cycle.

So how were children imposing some meaning on these disparate phenomena? The answer to this must be looked for in the different ways they imposed coherence on their explanations. Tracking through each individual child's changing explanations, there was some coherence built around the phenomena themselves. There were examples of children maintaining consistent views about puddles, for instance, yet having different views about clothes. Coherence was also evident in explanations generated in the same setting. Children would make links between phenomena in one interview, only to subsequently lose this and revert to incoherence. Sometimes this seemed to arise from the support provided by the situation, for example in response to interview questions which were framed similarly, or the flow of ideas in classroom discussion. At other times, there seemed to be a sense in which children would try out an idea (for instance, Amy's idea of water "floating" around, or of water drying up into perceived causal objects such as the fan blades or metal, or another child's image of a clash between hot and cold) and run with it during the interview or even across a span of time, independent of any input. Coherence was also often embodied in the use of language, particularly metaphorical language.

Larinda — exemplified the struggle with an "up – down" dichotomy

Larinda seemed to be in two minds about the fate of evaporated water. Her explanations represent two distinct conceptions vying for dominance; one with an upward, and the other with a downward focus:

Drying clothes scenario (13 March, initial transcribed probe):
Larinda: The water has gone to the bottom of the grass and soil and the washing is drying because of the sun because it is very hot.

The disappearing puddle (20 March, transcribed response after activity):
Larinda: The puddle dried up to the clouds because the sun dried it up and took it to the clouds.

Puddles (23 March, class discussion):
Larinda: I think the water went under the asphalt and under the school.
Teacher: So if I lifted the school up I'd see our puddle under the school right now? You're shaking your head. No? Where would it have gone?
Larinda: To the clouds. (And shortly after)
Larinda: It went into the grass.

In the September interview Larinda referred to the puddle soaked up into the ground, and going underground.

Jamie — a highly visual and literal sense of location

Jamie is a very visual child, focusing on his art work which is very detailed and individual. He seems to have a very visual/literal sense of the subsequent location of the water, as well as being sensitive to shape and colour.

Drying clothes scenario: (initial, transcribed probe, 13 March):
Jamie: The water has dripped down into the ground and now the water is in the ground (Jamie's drawing shows a careful profile of grass with water lying concentrated underneath).

Puddle (20 March, transcribed probe):
Jamie: When we left the puddle might have disappeared. It went into the sun.

Drying clothes (26 March, transcribed probe):

Jamie: ...the sun came in a bit and took the dark colour of the material. The water went out the door with the sun.

Puddle (2 April, interview):
Jamie: Aaah...I think (the water had gone) in the clouds because when we all went home Mrs W saw a cloud and it was the same shape as the puddle. So I thought that maybe the puddle drinked up into the cloud and made the cloud into its shape so that it could fit in.
Drying clothes (17 September, interview):
Jamie: (The sun) shines on the wetness and it sort of dries it up into a cloud. Like how we did that puddle.... (It's) sort of the same. Mrs W said it went up into a cloud so that was my idea.

Amy — a playful approach to ideas and a caring narrative

Amy's explanations reflect three distinct sub-themes; that of water contributing to the maintenance of soil and worms (setting the science within wider concerns), a water cycle image with strong hot/sun vs. cold/clouds/shade dichotomy, and an image of water floating from place to place in conjunction with this. She is explicit at one point about it being acceptable to hold different ideas about phenomena. There are a number of ideas within Amy's conceptual grasp, and she explicitly plays with these.

Drying clothes (13 March, initial transcribed probe):
Amy: The water went down to the soil and the flowers grow because they were near the water. It went down to the soil and dried up. When the sun was out it would have been dried

The disappearing puddle (20 March, transcribed response after activity):
Amy: The water goes up to the clouds. It *goes round in cycles* until it finds a shady spot and then goes up to the clouds.

Puddles (23 March, class discussion):
Amy: I think *it floated away* and then it dried up somewhere in the sun where it wasn't raining.
Later —
Teacher: You think it disappeared into the ground. What do you think Amy?
Amy: I think *it floated somewhere* until there was a drain in front of it.
Teacher: On Friday you told me that when puddles disappeared they went up into the clouds. Do you still think that or do you think they disappeared into drains?
Amy: I think what I said and I think what I said.
Teacher: You've said two different things?
Amy: I think both of them because sometimes I have different ideas and I still think the ones that I always said at first.

Drying clothes (17 September, interview):
Amy: (The water goes) in the soil. It makes worms feel nice and it makes the soil get moist.

Amy has a very literal interpretation of the water cycle, taking it to mean a circular path for the water. She often uses what we are calling 'instructed speech'; favoured terms that she has adopted from instruction. She tends to use terms such as cycle more or less appropriately, but without conceptual substance. She is quick to say "I don't know" when she cannot find a pattern of language she can employ easily. Amy had learnt technical language from her father, with whom she has a close relationship. Her teacher saw this as central to her positioning with respect to knowledge, but it was interesting to see Amy's positioning in the class change over the year as she adopted a strongly gendered 'I'm a friend' discourse both in class and in interview, as will be apparent in a later quote.

The reversion from an air or water cycle notion to a just like that or displacement into notion was common. The children seemed to have been influenced by the context of the activities and the class discussions to consider the location of the water as an issue, and in some cases to explain it as having gone into the air. These ideas appropriated by the classroom discourse could not, however, be properly scaffolded since the children lacked a conception of air and vapour that would enable the construction of a plausible model, they lacked experience of evaporation phenomena. As we shall see below, their epistemological perspectives were also limiting.

Chad — the power of prepositions

Chad had a strong, but varied location theme during the sequence. In explaining the drying fabrics activity he links causal and location ideas. These are strongly linked by his use of the preposition "into."

Drying clothes (13 March, initial transcribed probe):
Chad: Drip drop. Drip drop. The water sinks *into* the grass.

Evaporation from a frypan (March 19, transcribed probe):
Chad: The water dried up *into* the metal.

The disappearing puddle (20 March, transcribed response after activity):
Chad: I think the water went *into* the concrete.

Drying fabrics activity (26 March, transcribed probe):
Chad: In the sun the water will drink up *into* the sun. It will go slowly. In the wind the water will go *onto* the fan's blades and dry up when the fan stops.

There was sometimes confusion as to whether the explanation should deal with causal factors (the sun, heat, fan) or with the material effect. Children tended to focus on one, or the other. Children often associated the cause of evaporation with the location, possibly as a fall back explanation. The water was thought to go to the sun, or in Chad's explanation of a fan drying wet cloth, to the blades.

There was a lot of repetition of phrasing that seemed to support the maintenance of coherence in conceptions, repeating an earlier finding (Tytler, 1998a). This included persistent references to the sun, to water "floating around," or "dripping." We have seen examples of these in the transcripts above.

Metaphorical language seemed to be instrumental in imposing a coherence on children's views. Water going 'into' a variety of surfaces was used persistently over a long period of time by both Chad and Emily, and Rosalie talks of water going "up to" the sun or sky

Evelyn — preposition as metaphor

Evelyn talked constantly about water "drying up." The metaphorical power of this expression was evident in the way it seemed to focus her attention on an upwards, outwards transference of water. Evelyn's use of prepositions seemed to indicate a metaphorical linking of location through language. During the sequence the word "into" appeared a number of times. In the September interview her language changes to "up."

Puddle (23 March, class discussion):
Evelyn: (The water) *dried up into* the soil.

Drying fabrics activity (26 March, transcribed probe):
Evelyn: In the wind it will *dry up* quickly. The water goes *into* the air.

Puddle (2 April, interview; "RT" in the following is author 1):
RT: What happened to the puddle?
Evelyn: It *dried up*.... Because of the sun.
RT: Where did the water go?
Evelyn: I don't know.

In the September 17 interview she continues with the 'dried up' phrasing and launches from this to an image of water moving upwards, then later contrasts water "drying up," with water "staying in" when plastic is put over the top. "SP" in the following is author 2.

Evelyn: Some of the bits (of the puddle) *dried up* ... by the sun.
SP: Where did the water go?
Evelyn: *It went up*.... We didn't see it because sometimes like water is white *and it goes up* when you don't see it *going up*.
SP: What about when you made some puddles inside. You had some on the plates. What happened there.
Evelyn: Some of them *dried up* cos they didn't have any plastic on.

SP: And for those with plastic on.
Evelyn: The water *stayed in.*

Rosalie — linking causal power and location

Children could cast their explanations of evaporation either in terms of the cause of the process (mostly the sun) or what happens to the water during the process. The two approaches were sometimes confused, with children thinking the water went to the sun, thus linking location with the causal agent. Rosalie's insight concerning water travelling upwards is strongly linked with her image of the sun as the causal factor because of its strength, or hotness. Five months later she drops this idea of upward displacement in favour of a 'soaking in' notion, but the centrality of the sun is retained.

Drying clothes scenario (13 March, initial transcribed probe)
Rosalie: The wet went *up into the sun.*

The disappearing puddle (20 March, transcribed responses after activity and class discussion):
Rosalie: The water went *up to the sun* ... because on hot days its got to go *up to the sky.*

Drying fabrics activity (26 March, transcribed probe):
Rosalie: It will in the cupboard. It will take a short time because its so dark in there. When it dries because its dark. Water goes *up in the sky* because there might be hole in there.

The puddle (2 April, interview):
Rosalie: The sun might have dried it up.... And the lines were just there but the lines couldn't dry up because they were *too strong for the sun.*

Drying clothes (2 April, interview):
Rosalie: It went *up to the sky* because *the sun's very hot* and it dried that up.

Five months later she drops this "upwards" notion for a different preposition, but the importance of the sun remains.

The puddle (17 September, interview):
Rosalie: When it dried up it turned into some concrete.

Drying material in the sun (17 September, interview):
Rosalie: It gets dried up... because *the sun's really hot.*
SP: When its in the hot sun what happens to the water?
Rosalie: It dries up.

Epistemological Views: The Meaning of the Sequence

Given the range of intersecting narratives, and different ways that children constructed the meaning of the different classroom events, it is not surprising that they would not take the same view of the purpose of the sequence as the teacher. The task associated with each of these classroom events was different for each child, and this has epistemological implications in terms of the nature of the knowledge claims the children believed they were accessing, and the nature of the justifications for these. In the interview sequences it was clear that children did not see the activities as linked.

Kaye, with prompting, identified water as the common link, but did not mention any change phenomenon. She and Amy saw the presence of the researchers as the common defining factor. Chad identified the meaning of each activity by its context and social purpose.

RT: What sort of science, what sort of things did you find out?
Chad: That's cooking experiments (the frypan). This is weather experiments (the disappearing puddle) and this is wet and cold (fabric drying). And that is a water experiment (puddles in the classroom?)

Jamie does not understand the question about links between the activities at all.

RT: Okay and these other things that we did were they similar to that in any way, or different? Why did we do them all together? What do you think we were studying?

Jamie: Do you mean what do you think we were doing with the puddle?
RT: With all of them, with the clothes what happened there?
Jamie: Well the one on the sun dried quickly and the when the...the clothes in the sun dried up very quickly and it dried quicklier (sic) than all the other ones in the sun.
RT: Do you think that one and the puddle one were similar in any way?
Jamie: Well some were because...were dry and some were not.
RT: What did you think you learnt from the science we've been doing? What have you learnt?
Jamie: Mmmm...aaah...umm...
RT: Are there things you know about that you didn't know before?
Jamie: Yeh! Yeh! Now I know that puddles go up into the clouds and I know clothes in the sun dries up very quickly and now I know when you...salt in the frying pan with water for a long time you get a heart shape.

Learning and Children's Subjectivities

Thus far in this discussion we have been looking at children's conceptual concerns in relation to explaining and linking these evaporation phenomena. In examining how children interpreted the purpose of the classroom activities, identified their salient features, and constructed explanations of these phenomena, other dimensions of their thinking became apparent, associated with the way they positioned themselves in relation to the classroom and to science. We think of these as personal and social narratives that competed with the teacher's conceptual narrative.

Personal / Social Narratives

During both the interviews and classroom sequences, individual children were captured by other, particular narratives that competed for attention in their construction of meaning. This led to different perceptions of the salience of different features of the classroom experience. The task for each child was different, and often quite different to the purposes of the teacher and the researchers.

Children's personal narratives were evident in a variety of situations, through discursive shifts that cut across the conceptual narratives. Chad, for instance, had a history of interest in science, and this was evident in both his thoughtful approach to conceptual engagement, and his enthusiasm in telling stories about his experiments at home. Amy on a number of occasions referred to water soaking into the ground for the purpose of creating moist soil that helped the flowers (March transcribed probe) or worms (September interview). Walter's discursive shifts centred round enthusiastic and speculative connections with technical matters.

Kaye — a compulsive story teller

Kaye had a need for adult recognition, and interwove compelling stories and intriguing associations with her conceptual insights, as a means of controlling attention. Her technique is to scattergun her associations, adjusting her stories until she discerns the real concerns of the attentive adult. Under these circumstances, it would be difficult to ascribe a particular conceptual "position" to Kaye, but she is capable of multiple and clearly articulated interpretations of events. Her explanations are built around images of water 'drying up' because of the sun, or going down into the ground, but these ideas are interwoven with rich narrative elements.

The disappearing puddle (20 March, transcribed response after activity):
Kaye: The water dried up pretty quickly and the water looked like a person with one eye. It goes down to the concrete and stays there.

Cloth drying (26 March, class discussion):
Kaye: I thought that the water had gone into a little hole in the ground and found a drain pipe to go to the sea.....and the tortoise was there in the sea.

Review of puddles in plates investigation (26 March, class discussion):

Kaye: Well in the fridge ones I recognised once that the one without plastic on the plate well what happened was it was drying up when you opened it because the air was trying to pull it up - the air was trying to pull it up but the water was pushing down..

Puddles on plates (17 Sept, interview):
Kaye: It would dry up because the sun is so hot and then if you're in a rocket and your rocket touched it will set it on fire.
SP: I know but this water was outside and this water was inside but they both dried up.
Kaye: Yes. Because sun comes through the windows.

There were a number of instances of children's recollections, and commitment to ideas, being centred about the role they themselves had played either in taking responsibility for classroom tasks, or generating ideas they had perceived reflected well on them. Jamie's commitment to the idea of water going into clouds, which he extended from the puddle to other situations, was associated with his pride at having made this suggestion to his teacher.

Larry — an ownership narrative

Larry describes the success of his own idea in the cloth drying experiment:

Larry: Um, well we put my one — I had one 'cause I had a good idea — my one went near the fan, one went in the fridge, one went outside where the new playground thing is except where all the grass is, and we had one on a shelf.
RT: Right, okay, and what happened?
Larry: Well the one with the wind, my one, dried quickest.

Walter (in the 23 March class discussion of the puddle) explained: "I think the water went into the chalk," which at the time seemed odd. The reason was made clear when in the September interview he reminisced about how he had been given the task of drawing the chalk lines around the puddle. In an interview 20 months later he referred to this again.

In the puddle activity, the gathering round the puddle, and the class foray to the drinking taps (it was a hot day) was a significant social event, and the camaraderie featured in many drawings and dictated accounts. Children's responses to the photographs often centred about their own position in the narrative, and that of their friends. Children often remembered, and featured, who had taken responsibility for which tasks. To this extent, the learning that occurred during the activity must be strongly framed within, and derive meaning from, these personal - social narrative elements.

Amy — science as a social event

Amy's memory of the puddle is strongly socially framed. In the April interview, she focussed on where she and her friends were in the photograph. When pressed, she casually asserted that the water "went away," and on further pressing claimed it went "up into the clouds." She describes the frypan activity: "We watched it and that was Evelyn and I must be round here. That's not me that's you."

Her relationship with other children became an increasing preoccupation during subsequent interviews. In the September interview she is still captured by her friend's whereabouts and foregrounds this and the allocation of tasks rather than the conceptual elements intended by the teacher: "I think it was about how long puddles last." "And what did we do?" "We...Kaye poured water in there...I think Jamie drawed the chalk and then Kaye poured it in and that was Evelyn in the picture but I don't know where I was."

Fantasy Narratives

Kaye's visual response to the puddle activity, quoted previously, became a feature of her memory of the event which influenced her eventual interpretation. Firstly, to repeat the transcribed account at the time. "The water dried up pretty quickly and the water looked like a person with one eye. It goes down to the concrete and stays there." In the April interview following the evaporation sequence, Kaye refers to water rising up out of the puddle, but the visual memory remains strong: "Well it looks like a person but then Mrs W got the chalk and

she drewed (sic) around the little puddles. So where it dried it looked a person with his mouth open and eyes with one eye like..."

In the September interview, the lines seemed to have totally captured her attention.

Kaye: This was when we were scienting (sic) puddles and I poured the water how we got the shape it looks like a one eyed monster.
SP: What are all those lines there?
Kaye: Well at the bottom the lines are for because the water kept on spreading over the ones so we had to keep drawing around and around and around ...
SP: The puddle kept getting bigger did it?
Kaye: Yes....

This alternative rendering (indeed misremembering) of the teacher's and researchers' purpose for features of the activities was very common for children in the September interviews.

Shared fantasy elements were sometimes introduced by inadvertent emphases in the lesson itself. For instance, the teacher introduced the electric frypan evaporation lesson by mixing the salt and water and referring to it as a "witches' brew." From that point the children seemed primed to see something magical happening, and Amy's references to dangerous "sparking" of frypans heightened this sense. When the water bubbled and evaporated principally from the electric element, leaving a circular pile of salt, the class became captivated by the 'love heart' that had appeared as if by magic. This love heart became the basis for a shared focus and collective interpretation, and appeared in many of the children's drawings. The explanation of what was happening was captured in many accounts by the image of froth, of sparking, and of associations with frying.

Kaye: The frypan shape went into a heart. The salt made the white bubbles. The water dried down into the pan. The steam came up and wet Mrs. W's hand and also the octopus. The water changed into steam.

Amy reacted to the witches' brew scenario in her transcribed account: "The frypan was sizzling because it got really hot. The brew got too hot so it spouted. I saw sparks going everywhere. I don't know what white stuff is. The water got hotter so it sparked and popped ... went down into the pot." And five months later the heart shape is still persistent even though she denies any other memory of the event:

Amy: First it went into a heart shape and that's when I really did like it and then somebody was starting to switch it off but not one of the kids.
SP: What did we do there? What was that all about?
Amy: Well it was about cooking something but I can't remember what we cooked.

In the April interview the witch image was persistent for Kaye but she had lost all sense of water changing into steam: "Mrs wicked W was pretending to be a wicked witch and we put some salt and water in and we mixed it and we put it in the frying pan and it bubbled up...The water must have dried up onto the plate under the pan." In September Evelyn had reconstructed the event to have entirely new features: "Yes that was about when it was summer and we were doing...when Mrs W was making a broomstick. She was 'tending to make a....'"

Implications

For Views of Learning

This research demonstrates the complexity of the process of learning in classrooms. What is clear, by charting the changes in individual children's responses, is the complex set of conceptual and personal — social factors that interact to frame learning in science. These children brought different and multiple views of salience to each of these activities, determined not only by the nature of the conceptual challenge, but also metaphor, epistemological perspectives and personal and social narratives including fantasy.

The conceptual aspects of these children's stories are of central importance. The findings firstly provide evidence concerning children's ability to recognise the ongoing existence of

water during the evaporation process. These children, with support, regarded the question "Where did the water go?" as legitimate and interesting. However, they tended to avoid the question when it was difficult, reverting to simple perceptual statements. The changing nature of their commitments to this matter conservation principle, over both context and time, illustrates the difficulty of ascribing a particular conceptual position to a child. This is in line with previous findings (e.g., Tytler, 1998a; Rahayu & Tytler, 1999).

The ideas of water displacement, either into the ground, or up to the clouds, seemed to offer no serious challenge for these children. What was fundamentally difficult for them, however, was the idea that water could be present in non-perceptible form in the air, or atmosphere. Even when this idea was voiced, and acknowledged and encouraged by the teacher, it seemed to disappear without trace on subsequent occasions. The idea clearly contradicted their normal ways of looking at evaporation phenomena. A large part of the difficulty is that these children do not have a working mental model of the atmosphere and air, or of the form in which water might exist in the air. They also faced challenges in the form of mastery of the language associated with evaporation which is both metaphorical and subtle; "soaking into," "drying up," "going into the air," "up to the clouds," "floating around and out," "staying in" etc. Understanding evaporation is dependent on mastering these linguistic tools representing changing location.

The other task facing them involved mastery of the shifting forms of explanation, sometimes involving causal statements, at other times focussing on changes in form and location of the water. While adults work readily with both forms, children confuse them. A critical task for these children is to learn what sorts of answers adults might expect to the question, "what has happened to the water."

Mastery of these disparate conceptual elements cannot be simply seen as an act of learning by an isolated individual, but is fundamentally tied to the child's participation in discourse communities that represent these ideas. The classroom provides a major representation of this scientific discourse community (Driver et al., 1994). Increasingly over the primary school years children are invited to participate in adult forms of explanatory discourse. Classroom discussions of "Why has the puddle disappeared?" and, "Where has the water gone?" establishes what questions are of interest, and models the nature of the conceptual tools that are available to answer them (principles of change of state, and of conservation of matter). The classroom curriculum practice of bracketing these phenomena together models the use of these conceptual tools to make links between separate phenomena, and establishes the scientific principle of generalisation.

To understand the potentialities in this classroom setting for learning about evaporation, one can usefully access the conceptual change literature, or the Piagetian literature, for interpretations of the conceptual difficulties themselves for children of this age. One can look further, at the role of other dimensions of individual thinking, such as epistemologies, and beliefs (Strike & Posner, 1992; Duschl & Gitomer, 1991; Pintrich, Marx, & Boyle, 1993). Beyond this, to understand the complex features of the classroom setting that sidetracked these children, or supported them to construct meaning out of these activities, one must look through the wider lens of socio-cultural and situated cognition perspectives on learning (Resnick, Levine, & Teasley, 1991; Wertsch, 1991; Hennessy, 1993; Hennessy & Murphy, 1999; Lemke, 2000) to consider children's views of themselves as participants in this community, and the role of language and narrative in framing their responses.

Indeed, what is striking about these children's responses is the way the conceptual learning is woven through by narrative. Conceptually, their responses to the tasks were complex and unstable. Their construction of explanations, and what they see as salient in each of these activities, is centrally bound up with their growing sense of who they are in relation to schooling, to the class, the teacher and the interviewer. What they focused on, in relating and in remembering each task, was centrally concerned with their own view of their role in relation to the task and the knowledge. For each of them the conceptual problem was framed within intersecting narratives of identity, to do with themselves as story tellers, as budding scientists, as friends, or as children of knowing parents. These wider perspectives breathed meaning and life into the knowledge they sought and expressed.

The changing of conceptions, in this case between explanations of where the water went, or to an appreciation of the central role of air, and the gaseous form of water, is not simply a rational process; it is a social process. The complex ways in which these individual children responded to the activities interacting with the classroom setting can be more productively appreciated through socio-cultural perspectives, which ask how we teach human beings to

engage with experiences and ideas, and how comfortably these sit "with differently configured and socially positioned identities" (Lemke 2000, part 4, p. 5). For these children, accepting a scientific view of evaporation involves both a conceptual and a social/personal challenge; it requires specific conceptual connections to be made, and also asks for a reordering of priorities as to what is attended to and valued.

To make sense of the findings of these studies, therefore, it is necessary to view them through a number of lenses. From our perspective, both the conceptual change literature, and socio-cultural perspectives provide valuable insights into these children's learning. They are complementary windows through which the complexity of children's learning can be viewed.

For Teaching

Teachers need to be sensitive to these intersecting conceptual, personal and social narratives. From our observation of Sally, the classroom teacher, and our experience of other effectively functioning classrooms, teachers in fact are able to recognise and respond to the existence of these interlocking narratives in their practice. This capability is part of what is understood by teachers' craft knowledge. We need, however, to find ways of supporting them in recognising the potentialities of these narratives as children's frameworks for learning. One of the unfortunate features of the way science knowledge is currently characterised, in terms of specific and sequential conceptual outcomes, is that it tends to undermine effective teachers' sense of the complexity of the learning process.

Teachers need to be sensitive to the rich range of meanings that can arise from the different features of classroom activities — as with the salt in the frying pan or the children's image of the lines round the puddle, or indeed the different potentialities of activities for cuing particular aspects of science understanding. They need to be aware of the importance of modelling the discursive tools of science, such as highlighting the importance of the question "Where has the water gone?" as a representation of the power of the scientists' view of matter, or the focus on evidence to support the framing of explanations and arguments; and

For Research

Much of the conceptual change research assumes some degree of coherence in students' conceptualisations, that can be probed on a particular occasion with some degree of confidence, and that undergoes a relatively predictable set of transformations over time. This current study raises questions about both these assumptions. While it may be possible to discern differences in conceptions of cohorts of students of different ages, or who have had different learning experiences, it is clear that individuals cannot be said to 'have' a conception independent of either particular phenomena, or the particular social context. This raises both a theoretical question concerning the nature of science knowledge, and also a methodological question concerning the interpretation of a student response in interview or other probe. It is clear, from this study, that it is dangerous to extrapolate from one response to presumptions about understandings conceived as stable elements of cognitive structure. To build up a picture of children's science understandings, considerable insight is afforded by looking at responses across different phenomena, and across time.

Discussion

At one level, this classroom sequence could be viewed as a failure, since the target idea, that of an understanding of evaporation, was not achieved in any substantial scientific sense. To that extent, the research is not offering a serious challenge to the assertion that evaporation is a difficult concept for such young children and perhaps best left for serious treatment when they are older. The study has, however, established that some of the ideas that have been considered to be inaccessible to such young children are in fact quite accessible, and that their thinking is more accomplished and complex than might have been expected from the Piagetian or the conceptual change literature. Secondly, from these findings we would assert that to understand learning in classrooms, as we must do if we are to provide advice and insights for teachers, we must go beyond the simplistic position that at some stage children will be ready to access a scientific conception. The notion of readiness is challenged by the complexity of these

children's conceptual responses, and any simple notion of what is 'scientific' and what is not, is challenged by the multiple ways these children accessed and interpreted these phenomena.

To choose such a challenging topic to explore with these children was in some senses an advantage in that it required them to cast around for multiple resources to respond to the conceptual challenge, and brought these narratives to the surface. Our experience with other topics with these children, and indeed their conceptions of evaporation during the following year, would indicate that all significant learning is suffused through with these personal and social narratives. It would be expected that as they move through their schooling the particular ways they position themselves as learners will change, so that fantasy, for instance, may drop away to be replaced by other, more acceptable narratives. As we continue to track these children as they increasingly access scientific ways of interpreting the world, and become more acculturated to adult expectations of explanation and evidential argument, it will be interesting to explore changes in the ways these personal and social narratives are expressed in their accounts. We are convinced, however, that learning will remain both a very personal and a fundamentally social process, and that teachers must be supported to recognise this.

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