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J. Robbins
Monash University

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YOUNG CHILDREN THINKING AND TALKING: USING SOCIOCULTURAL THEORY FOR MULTI- LAYERED ANALYSIS

JILL ROBBINS
Monash University

Abstract

Traditionally in science education, research on young children's thinking about the natural and physical worlds is categorised and explained in terms of the mental models or schemes they purportedly hold. Frequently informed by Piagetian or constructivist paradigms, their ideas are commonly described as being alternative, naïve, untutored, erroneous - or other deficiency model terms. However, when sociocultural theory is used to inform data generation and analysis, a different and more positive explanation of their thinking can be made.

This paper will present a study that used firstly Rogoff's (2003) three foci of analysis followed by aspects of Vygotsky's (1987, 1997, 1998, 1999) theorising to inform the analysis of conversations with young children about the sun and rain. This provided an innovative way for considering how children develop ideas about the world. It also revealed that their thinking is often complex and powerful. Some implications for science education and for research with young children will be briefly addressed.

Introduction

For a number of decades science education research, particularly in relation to young children's thinking about their natural and physical worlds, has been strongly influenced by the ideas of Jean Piaget. Continuing up to the present time constructivism, deriving from Piagetian theorising (or *interpretations* of Piaget's work), is the most routinely used paradigm within many of these science education research studies. Commonly it is contended that young children's thinking about the world can be explained in terms of the particular mental schemes (Piaget, 1972, 1973) or mental models (Vosniadou & Brewer, 1992, 1994; Samarapungavan, Vosniadou, & Brewer, 1996; Vosniadou, Skopeliti & Ikospentaki, 2004) they hold.

While much of this body of research has been useful in helping us understand how children come to know their world, increasingly there are challenges made concerning the ideas of the universality of childhood upon which many of these studies are founded (see, for example,

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Göncü, Tuermer, Jain & Johnson, 1999; Mayall, 1999; Woodhead, 2000). Somewhat problematic also is the apparent ease with which children's thinking can be categorised, and the manner in which it is often described as being 'alternative', inadequate, naïve, erroneous, untutored, or other deficit model terms (see, for example, Stepan & Kuehn, 1987; Russell, Bell, Longden & McGuigan, 1993; Hodson, 1998), commonly held by many of the constructivists. In contrast, years of experience in working with young children has led me to believe that their thinking is complex, dynamic, often collaborative and contextualised – characteristics that are frequently not evident within the science education research. This, in turn, lead me to question whether the traditional methods of data generation such as 'clinical method' (Piaget, 1973) or semi-formal interviews, together with simplistic forms of categorisation of children's responses (for example, animistic, anthropomorphic, artificialist, magical, et cetera) are the most effective or authentic ways of revealing the richness and at times sophisticated nature of their thinking. Would the adoption of another theoretical informant in data generation and analysis, namely sociocultural theory, and in particular aspects of Vygotsky's theorising, offer another perspective?

Thus, over a number of recent years, I have attempted to develop a 'new' way for considering how young children's thinking about the world develops. What has resulted is a framework that, informed by sociocultural theory, uses two approaches to analysis of conversations or interviews with children – firstly Rogoff's (2003) three foci of analysis followed by aspects of Vygotsky's (1987, 1997, 1998, 1999) theorising.

The framework that has been developed arose through an eighteen month study involving conversations with young children who attended a co-educational independent school, affiliated with the Uniting Church, situated in the outer South-eastern suburbs of Melbourne, Australia. The participants in the study were fifty-seven children, aged three to eight years of age, who were spread across five classes – a three-year-old preschool group, a four-year-old preschool group, a prep (beginners, new entrants) class, a grade one class and a grade one-two composite class. After a lengthy period of part-time participant observation, the major focus of the data generation was children's thinking about natural phenomena, mediated by conversation, drawing and other cultural tools. Individual children and I participated in extended tape-recorded conversations, with the children being invited to complete drawings during the discussions. Although each conversation began with the question 'What do you think happens to the sun at night time?' or 'How do you think rain happens?' there were no other preset questions, and the conversations tended to follow the children's responses. This was repeated again twelve months later. These conversational/drawing activities, which lasted for a minimum of fifteen minutes, and in some cases an hour (most about half an hour), were conducted at the school, in the children's classrooms or multi-purpose rooms directly off classrooms, or in the school's art complex, during regular work time. That is, the normal business of the classroom continued as we engaged in the research activities.

The children's teachers indicated that a number of them had informally talked at some stage about various natural phenomena (such as the sun, moon, rain, wind, weather), and three of these teachers had consciously attempted to 'support the children's learning' in the topics raised. The children within the grades one and two classes (some of whom were in grade three during the second year of this study) had some formal teaching in Earth and Space Sciences, such as weather, the day and night sky, and the sun and moon. This was conducted by both a specialist science teacher and their own classroom teacher.

The purpose of incorporating drawings into the conversations was that it was anticipated that they, along with other contextually relevant signs and artefacts, might serve to mediate children's thinking, and with the establishing of shared meanings. Thus the aim was not to use the drawings as a product to be scored or analysed for indications of understandings or evidence of conceptual change, as some other studies have done (for example, Hayes, Symington & Martin, 1994; Vosniadou & Brewer, 1994; Shepardson, 2002).

Briefly, the research was conducted in the children's own contexts, using artefacts with which they had familiarity, and reflected somewhat more closely an 'everyday activity' than a formal interview might do. The data from the conversations was supplemented by field notes and informal conversations with various teachers and parents about experiences and activities the children and their families participated in outside of the classroom, and numerous aspects of the curriculum.

However, when faced with analysing the data, a number of challenges arose, the foremost of which concerned how a Vygotskian perspective could be applied to this process. While Vygotsky's writings, particularly his collected works, provide detailed critiques of the ideas of many of his contemporary theorists and complex descriptions of his findings, there seemed to be no clear set of guidelines that could directly be transferred to this study. Thus a decision was made to analyse the data on two levels. The first level was informed by Rogoff's (2003) three foci of analysis, and highlighted certain factors that appeared to be integrated with children's thinking. These issues were then further analysed from a Vygotskian perspective, as shall be discussed later in this paper.

Theoretical Informants for the Study

Rogoff's Three Foci of Analysis

From a sociocultural perspective, Rogoff's (1998, 2003) work on the three foci of analysis provides a useful conceptual tool for analysing research with young children. Importantly, it can highlight how children's thinking is integrated with and constituted by contexts, collaboration, and signs and cultural tools. In this approach, rather than focusing on decontextualised individuals, as dominant methods particularly in science education research tend to do, the focus of analysis can variously be on the participation of a child within an activity and how this participation transforms during the course of the activity (personal focus of analysis), the children's collaboration and relationships with others (interpersonal focus of analysis), and on cultural/institutional/historical factors (community or cultural or contextual focus of analysis), *with any one of these being in focus, while the others remain in the background*. Significantly, one cannot interpret or understand any of these planes of analysis without seeing how it fits into the ongoing activity.

Analyses that focus only on one of these foci (to the exclusion of others) and that present small extracts of conversations with children, as tends to occur in the dominant research methods, risk losing the multiple factors that are constituted with children's thinking. These can include the direct experiences of children, topics and issues taught at school or home or by extended family members, shared understandings (in contrast to those supposedly the child alone holds),

contextually relevant beliefs (often at odds with or opposed to those of the researcher), and the importance of tools such as television, books of various kinds, songs, drawing materials, and other artefacts that frequently are integrated with young children's thinking. Further, as a participant in the research activity, it affords reflection on the role of the researcher within the data generation process, and the extent to which this mediates children's thinking.

Vygotskian Perspectives

Vygotsky's theorising provides a complex way of understanding how both the natural/biological line of development and the social/cultural/historical line contribute to the development of children's thinking (Vygotsky, 1997). Through ongoing interactions with others, together with the mediation of various signs and tools, culture (or social ways of 'being') is internalised and the lower order mental processes with which children are born are gradually transformed into higher mental processes (Vygotsky, 1997).

Intermental to Intramental functioning

A central principle of Vygotsky's theory is that learning occurs first on an interpersonal (or intermental) plane, between a person and other people while engaged in joint sociocultural (or shared social) activity. It is then gradually internalised or appropriated and transformed on an individual (intramental) plane (Vygotsky, 1987, 1997, 1999).

As Vygotsky (1997: 106) explained,

...every function in the cultural development of the child appears on the stage twice, in two planes, first, the social, then the psychological, first between people as an intermental category, then within the child as a (sic) intramental category... We are justified in considering the thesis presented as a law, but it is understood that the transition from outside inward transforms the process itself, changes its structure and functions.

However, it is not simply the physical interactions between people that bring about learning and cognitive development. Signs and tools perform a vital mediating role.

Mediation of Thinking by Signs and Tools

Vygotsky (1999) contended that the external social world is gradually interiorised and transformed by the child through the mastery and appropriation of signs and tools, the most important of which is speech. Speech holds the foremost role in the organisation and development of thinking.

For Vygotsky (1987, 1999) the developmental path of speech proceeds from external social speech to egocentric speech (or speech for oneself) to inner speech. Significantly, egocentric speech has an important intellectual function, in that it forms a vital intermediary between the social and the individual, or external speech and inner speech, and is *an indication of the child's developing cognitive maturity*. This view differs from that of Piaget who saw egocentric speech as having no objective or useful function in the child's behaviour – it does not transform a child's thinking. For Piaget, egocentric speech is a symptom of the weakness or immaturity of the child's thinking, which will gradually disappear during the course of development (Vygotsky, 1987).

After a phase of being dependent on interpersonal or external social speech as a tool in accomplishing activities, and being guided by adults or more competent others when tasks are difficult to solve independently, children begin to develop the capacity to carry out activities *guided by their own speech* (Vygotsky, 1987, 1999). That is,

(t)he greatest change in child development occurs when...socialized speech, previously addressed to an adult, *is turned to himself* (sic), when, instead of appealing to the experimentalist with a plan for the solution of the problem, the child appeals to himself. In this latter case the speech, participating in the solution, *from an inter-psychological category, now becomes an intra-psychological function* (Vygotsky & Luria, 1994: 119; italics in the original).

Signs (such as speech) and other symbol systems (such as writing and number systems), and cultural tools (such as books, television and so on) bring a cultural heritage and history with them, and by learning to use these symbol systems and tools, and the practices in which they are used, people integrate and draw on the experiences of others (Luria, 1979, Vygotsky, 1987, 1997). Signs and cultural tools therefore make a link between culture and individual mental functioning, or as Davydov and Zincehenko (1993: 103) summarise it, '(f)or Vygotsky, determination of individual consciousness follows this schema: collective, social activity - culture-signs-individual activity – individual consciousness'.

Drawing is also a significant symbol system, and for Vygotsky (1987, 1998) indicative of children's level of thinking. During the preschool years, where the leading activity for the child is play and creating imaginary situations,

the child's drawing is still directly connected with play and presents the characteristic traits of the object in a graphic form. Drawing several objects at the same time is nothing other than a purely mechanical combination, a purely external uniting. At the second stage, the circle of the objects the child draws is extended and machines are included in the drawing. The child draws the external form in detail; the combination of separate objects has a more connected, complex character (Vygotsky, 1998: 111).

Gesture is also an important sign or tool, and one that Vygotsky (1997) linked with drawing and writing. ‘The gesture is writing in air and the written sign is frequently simply a fixed gesture’ (Vygotsky, 1997: 133). When drawing, Vygotsky believed that a child often makes a transition to dramatisation, indicating through gesture the *intention* of the drawing, and then repeating that gesture with a line on paper. That is, children, especially within the early childhood and preschool years, may specify by gesture what they are thinking about or intend to draw, and then repeat that gesture in their drawings (Vygotsky, 1997). This is a form of planning, and as such can be an indication that thinking is moving towards a higher level.

The Development of Higher Order Thinking

From birth children possess a range of lower order mental processes, such as elementary attention, perception and lower order memory. Over time, with the mediation of signs and other symbol systems, and tools, these processes progressively are transformed into (rather than being replaced by) higher mental functions. Through speech particularly (especially egocentric and inner speech) children become less dominated by their perceptions, less impulsive and more able to control and direct their own thinking and actions, including their perception, memory, attention and other forms of goal-directed thought and activity (Vygotsky, 1997, 1998, 1999).

For example, when drawing Vygotsky (1998, 1999) demonstrated that speech initially accompanies or follows children’s actions. That is, at first children will simply draw, and then name parts of their drawing or they will describe to others the actions that they have just completed in the drawing. Gradually, the naming of the subject of the drawing will shift to the beginning of the process – the intention of the drawing is announced. From there on speech progressively serves a planning and directing function, moving to the intramental, inner speech level. There has been a gradual restructuring to higher psychological processes. Thinking has moved to a higher level (Vygotsky, 1987, 1998, 1999).

The development of memory was one of the aspects of higher order thinking that was of particular interest to Vygotsky and his colleagues. In their studies Vygotsky (1987, 1997) identified two kinds of remembering. The first type he described as direct remembering (to remember without the aid of some supplementary means), while the other is mediated remembering. He contended that when children remembered with the aid of some auxiliary means (mediated remembering) they were able to perform differently on tasks. He declared that

(f)or children who used signs and auxiliary operations, the task required not memory so much as the ability to create new connections or new structures. It required a rich imagination and sometimes well developed forms of thinking. That is, the task required the use of psychological qualities that are not essential to direct remembering (Vygotsky, 1987: 308).

In early childhood children commonly use direct remembering, or remembering without auxiliary means. During this period the young child’s thinking, which Vygotsky (1987) described as among the most basic and central mental functions, differs from that of a more mature child.

As he eloquently stated, ‘to think is to remember for the young child, for the adolescent to remember is to think’ (Vygotsky, 1987: 309). As the child learns to use artificial means (signs or symbols) to aid memory, higher order behaviour develops (Vygotsky, 1997).

The analysis

As stated earlier, challenges arose initially in attempting to apply a Vygotskian perspective to the analysis of the data generated. Therefore, the first stage was to use Rogoff’s three foci to pinpoint factors that appeared to be integrated with their thinking. These factors were then later further analysed using aspects of Vygotsky’s theorising.

Rogoff’s Three Foci of Analysis

Contextual or Community Focus of Analysis

At this first level of analysis, a range of important issues came to light, related not only to children’s thinking, but also, in a broader sense, to research with children in general. Examining the conversations through Rogoff’s contextual or cultural lens highlighted number of tools and artefacts that appeared, within this particular study, to be integrated with their thinking - including drawings, books, television programs (news and children’s programs), videos/DVDs, songs, chants or rhymes and gesture. That is, it became obvious that these artefacts were, in addition to the talking that was occurring, performing a strong role in the mediation of thinking.

This lens also highlighted issues associated with *time* in research activities with children. For example, when the conversations were relaxed and unhurried the quality of the interchanges and the depth and complexity of their thinking was most evident. Time allowed many of the children to think beyond levels revealed in more traditional forms of research utilising semi-formal interviews. For example, in an extended conversation in which time was not a confining factor, Ollie (5.6), moved beyond thinking simply about the sun setting at night and then rising in the morning. In doing this, his thinking surpassed the somewhat simplistic answer to the initial question, ‘*What happened to the sun at night?*’ (Ollie: ‘*When the sun comes down, the moon comes up*’), to a more complex consideration of the process by which the sun appears to sink in the West and rise in the East, and the effects this has on the Earth (‘*Well, usually it’s a hot day, and a...cold night*’).

Other more subtle, but nonetheless significant, issues revealed included cultural histories, and the values and beliefs held by others (such as family, school and various cultural groups) within the children’s communities. Given that the school is an independent Uniting Church school, it was not necessarily surprising that God was attributed to be the source of rain or the reason for the sun going down at night by eighteen percent of the children. Explanations such as ‘*God spits*’ (Paddy), ‘*God makes the sun go down*’ (Liam), or ‘*God controls everthing* (sic)’ (Paul) were relatively common. Rather than simply explaining this as being an example of what Piaget (1973) referred to as *integral artificialism* or *implied animism* (a fundamental belief that natural phenomena are artificially ‘manufactured’ [Piaget, 1973]), this might reflect a view that is supported at school and/or home. It is demeaning to dismiss these ideas as immature if they are in

fact shared understandings or cultural histories that are scaffolded within the home or school community.

Finally, the philosophy of the researcher, and the often unexamined taken-for-granted practices and 'ways of doing things' in research and teaching also became evident through this contextual lens. For example, issues associated with power, questioning techniques (especially the kind of questioning commonly used in Western world classrooms, such as known-answer questioning and question-answer-question-answer formats [Roberts-Holmes, 2005]), the presence or lack of open-mindedness during the conversations, and the manner in which the following of research 'traditions' can have an immense effect on the research activity, and in turn, children's participation within this, were frequently apparent.

Interpersonal Focus of Analysis

The interpersonal focus of analysis highlighted above all the impact of proximal others (those present during the activity) on the research. A significant factor was the depth of the relationship between the researcher and the children (emphasising the need for time to build relationships for successful research activities with young children), as was the style of interaction. As an example reflection on the style of questioning used during the conversations lead to attempts to modify the style of interaction. As a result I became more relaxed in the activity, allowing the child to set the direction of the conversation (even when it appeared that the child was 'off topic'), and let go of some research conventions (does the child hold a scientific view?). Consequently, the conversations became more elaborate and extensive.

A key concept in Rogoff's (1998, 2003) theory involves transformation of participation – or ways in which a person develops through involvement in an activity, changing to be engaged in the situation at hand in ways that contribute both to the on-going activity and to the person's preparation for future involvement in similar events or activities. Ways in which a researcher develops and changes through participation in the research activity, can in turn lead to changes in the responses of the children, and ultimately a far better understanding of their conceptualisations. These factors are frequently not overtly addressed in traditional forms of research, where the fact that children's participation in the research activity is mediated by another (the researcher or teacher), and the effects of this mediation, receives little or no attention.

Also brought into prominence was the strength of understandings and beliefs *shared* with or distributed between more distal others (those not present within the research activity, but important to the children). Frequently discussed were ideas about the sun and moon or the rain and clouds that were communicated by others in non-school contexts. Though not all children were asked the source of their ideas, twenty-five percent (25%) children in the study (including many of the six-, seven- and eight-year-olds) gave their mother as the source of their understandings, and fourteen percent (14%) said they knew about something from their father. Grandparents were also regularly mentioned, and occasionally siblings or friends. This is significant when compared to the very few times that children related learning anything at school. Of the more than two hundred conversations held over some eighteen months of this particular study there were only two occasions where a child indicated that s/he had learned in school something related to the topics we were discussing - and in both instances other sources were also mentioned.

Personal Focus of Analysis

The personal focus of analysis revealed a range of important issues beyond merely the specific concepts children held. Often evident was that, when drawing, many children (both older and younger ones) were engaging in egocentric speech, revealing through this a dynamic, evolving or meandering nature to their thinking. In a conversation with Ollie (5.4) he moved from talking about the sun going down in the west and coming up in the east, to the sun coming 'down from the hot' while the 'moon comes up from the cold', to cold nights in Mexico, to the shape of the moon, to singing *Twinkle, twinkle, little star*, to colours for drawing the sun and sky at different times of the day, back to the sun and east and west, to the sun at different times of the day, to the planned Christmas concert, to the song *Stand by Me* (Lieber, Stoller & King, 1998) and its relationship with night and the moon, to the man and lady in the moon and the shape of the moon, and so on... This demonstrates how his thinking is *evolving*. It contrasts with other forms of data generation and conversational analysis where thinking is regarded as *static*, and what a child says at one particular point in time is regarded as a definitive representation of her/his ideas.

While this meandering nature to thinking was particularly evident in the conversations with Ollie, it was common to many of the children. Frequently the conversation would drift to talk about family, or experiences children had outside of school, and back again to the initial topic. In addition, perhaps through the aid of the drawings, the children were able to remain focused on, or to re-focus on, themes of the sun or the rain for considerable lengths of time. Thus the discussion was rich and in many instances extensive.

Also revealed was the existence of multiple views about a certain phenomena. For example, in Charlie's (7.3) conversation about the sun, he variously expressed the view that the sun goes 'away behind the clouds', that it goes 'over to the other side of the world', to 'another country', that 'the moon goes over it', the clouds 'go over it', then the sun comes 'if it's a sunny day', and finally that the sun goes down then rises.

What was very noticeable was that many of the children held rich everyday concepts, developed through direct practical experience and interaction with family members and in some cases their teachers and others at school and within the environment. While these concepts were vivid and situationally meaningful, and often highly imbued with personal significance, they were not integrated into a system of related concepts. Thus most of the children could talk freely about what they had observed, experienced or come to believe through family interactions. They appeared far less confident in attempting a scientific explanation – though there was evidence of reflection on thinking apparent in some of the children. None held what could be termed true scientific concepts (concepts that are deliberately and consciously used, are systematic, and exist within a logical, hierarchical network of connected or interrelated concepts), a factor that might not have been evident had the conversations been short and only the first few responses analysed.

The factors highlighted through Rogoff's lenses are summarised in Table 1, below.

Foci of analysis:	Factors highlighted:
Contextual/cultural focus of analysis	<ul style="list-style-type: none"> • Cultural tools, artefacts and signs (especially speech) • Cultural beliefs, values, knowledge and histories • The importance of time in research with children • The impact of research and teaching conventions
Interpersonal focus of analysis	<ul style="list-style-type: none"> • The impact of proximal others (those present in the activity) on the research activity – for example, the researcher, peers • The strength of understandings and beliefs shared with distal others (those not present within the research activity, but important to the child)
Personal focus of analysis	<ul style="list-style-type: none"> • The evolving or meandering nature of children’s thinking, or the dynamic character of thinking • The existence of multiple views at one time • The significance of egocentric speech • The developing ability to plan actions • Concepts – rich everyday concepts, but no true scientific or academic concepts

Table 1: Factors associated with children’s thinking revealed through Rogoff’s three foci of analysis

However, Rogoff’s lenses, while they serve to highlight a number of significant factors, do not, by themselves, explain adequately enough the course of development of thinking. When mapped and linked to certain Vygotskian ideas, such as intermental to intramental functioning, mediation of thinking through signs and tools, social to egocentric speech, and the development of higher mental functioning, a more complex analysis of the course of development of thinking can occur.

Vygotskian Analysis

Intermental to Intramental Functioning

Each of Rogoff's three lenses confirmed Vygotsky's central notion that learning occurs first on an interpersonal (intermental) plane, between people engaged in joint sociocultural activity, and that this learning is gradually internalised and transformed on an individual level (Vygotsky, 1987, 1997, 1999).

As indicated previously in the section on Rogoff's interpersonal focus of analysis, it was clear in the study that many of the children talked about ideas or understandings that were shared with others, and that their thinking was in many instances predominantly at an intermental level. That is, the ideas or concepts, cultural beliefs, values and knowledge they discussed within the research setting were those that were held by cultural groups important to the children – such as families. This is to be expected, as children interact with parents, grandparents, siblings and significant others from birth, and these family and community members 'actively seek to incorporate them into their culture and its historically accumulated store of meanings and ways of doing things' (Luria, 1979: 45). For example, in talking about the rain, Ollie states that '*maybe God makes water*', and that '*Well, my Daddy usually tells me some things... Well, God made the Earth... He did.*' On another occasion, when talking about the sun at night, he stated '*Well, the sun's made of fire... 'Cos Mu'... 'cos Mummy told me, it's made of fire*'. Similarly, Uma (6.5) related how her grandfather had discussed a relationship between lightning and thunder:

Ummm...what else have I seen? You can count 'cos if you want to see, ummm...if you hear thunder...ummm...count, an' then you'll get, um, some lightning... Ah...You can count to as long as you like. An' then you'll get it. No, you can count to a hundred even... You can count to eight. One isn't good enough. Two's good enough... Two, you can do. My Poppy told me this. An' then we started counting, and it was really good...until it started to rain.

However, as mentioned earlier, few of the children appeared to hold views that could confidently said to be derived from the social world of school – or at least, when asked, that they said they had learned while at school. That is, at the intermental level, there appeared to be more thinking shared between children and their home settings, than between children and their school setting. A number of possible explanations could be given for this. One is that possibly children have already internalised or transformed to an intramental level learning that is occurring at school. However, in the case of the topics we were discussing (the sun and the rain) this is unlikely, as they did not appear to be thinking in scientific or academic concepts (and presumably, though not necessarily, the teachers would be attempting to teach scientific concepts in these areas). Further, they did not state their teachers to be the source of their understandings. In addition, young children share more time in family activities than within school activities, and consequently the shared ideas from home settings are likely to be stronger. Thus they have more ideas and experiences from family settings to draw on. The activities they engage in at home are more likely to be practical (as opposed to the more abstract activities likely to have been encountered at school), and therefore more authentic and meaningful, and thus easier to talk about.

What became evident was that the ideas held by children were overwhelmingly everyday concepts. Further, it was revealed that they often hold *multiple* views at one time. Given that the children in this study were 'enculturated' within a number of different communities – family,

school, society and in some instances church – this is not surprising. However, during the course of the extended conversations, it became apparent that, over time, children were attempting to internalise, appraise and transform these often conflicting views and concepts, and to make them their own. That is, there was evidence of some movement in thinking towards an intramental level.

But *how* was this transmission of the external, social world and transformation to the internal, psychological level of the individual occurring? The first of these issues can be addressed through consideration of the role of signs and tools in the mediation of thinking (below), while the latter will be considered within the section on the development of higher mental thinking (following).

Mediation of Thinking by Signs and Tools

In this study, the talk the children and I were engaging in was obviously the major sign or tool that was mediating thinking. However, a number of different aspects of talk or speech were noticeable. In the first instance, speech was initially a means of communicating between researcher and child – a social relation between two proximal people. To begin with, speech was a tool for establishing contact and defining the focus of the activity. Here speech was occurring on an external, social level, as questions were asked, and responses given. Moreover, within the relaxed format of the conversations and the extended time frame, and especially with the addition of other cultural tools (paper and fibre-tipped pens), it became obvious that for many children speech was becoming more internalised. With this, speech became a means of organising and transforming thinking within the child. In other words, speech was mediating thinking (Vygotsky, 1987). This mediation was most apparent when children used egocentric speech – such as Ollie’s talk about the colours he would use in his drawing of the sunset, given in the section on moving towards higher order thinking, below. However, the children’s speech also reflected distal relationships. That is, the children brought to the immediate activity the voices of others through the shared meanings they discussed.

In addition to speech, another sign or tool that played a significant role in the development of thinking within this study was drawing. As described earlier, during the preschool years drawing is frequently directly connected with play, and when drawing several objects there may appear little connection between them. However, gradually the child enters a second stage where drawing becomes more mechanical, external features are drawn in detail, and connections between separate objects is more complex and elaborated (Vygotsky, 1998).

These characteristics were evident within this study. The drawing of many of the younger children had a playful characteristic about it, with inclusion of such things as pets, birds, friends and siblings in their drawings of what happens to the sun at night or how rain happens. Frequently objects in the pictures appeared to be unrelated in any particular manner other than they were placed at the child’s whim. Several of the older children, however, whose ages were nearing what Vygotsky, above, described as the second stage (ages 9 to 12), made conscious efforts to indicate the connections between objects. Thus, arrows indicating correlations, links and paths of movement appeared in the drawings of some of these older children. These, too, are indications of a

development in thinking, in which specific children have moved beyond thinking in isolated complexes and everyday concepts towards more scientific concepts, where they are beginning to see systematic relationships between various ideas, and are consciously and intentionally attempting to organise these ideas.

When the drawing and conversation was unhurried, some children suddenly began to sing. This singing, which under more formal approaches to research might be overlooked, or even discouraged, served to illustrate how for some children this is another tool which mediates thinking. As illustrated earlier, Ollie, for example, while drawing about the night sky, muses on how the grass needs to be dark green for the night. '*Dark's always for night. Night always has dark*'. This is followed by his spontaneous singing of the song '*Stand by Me*' (Lieber, Stoller & King, 1998), after which he indicates that he sees a relationship between our talk about the sun at night, and the lines '*When the night has come, and the land is dark, And the moon is the only light we see...*' Again this demonstrates that if the 'culture' of the research activity is one in which children feel relaxed and secure, researchers are more likely to uncover more complex and quite intricate levels of thinking, together with some indication of what particular tools are serving a mediatory role and how this is occurring.

Gesture was a further sign or tool used by a number of children, especially while engaged in social speech. Several of the children in this study at times used gesture in a manner which appeared to indicate that it was emphasising or clarifying their thoughts. Uma, for example, used gestures while talking about lightning, Peta when describing the '*sprinkling*' of rain, Goran when describing filling a bucket, and Ollie to emphasise the location of the Poles, the '*wooshing*' of the wind and the movement of the sun. This gesturing was at times linked with statements about what children intended to draw, an indicator of mental functioning moving towards a higher level (Vygotsky, 1997).

Moving towards Higher Order Thinking

Vygotsky (1997) emphasised that it is important to study the *process* of development, rather than merely the endpoint. Though the course of development of higher mental functioning takes many years to come to fruition, and it is not suggested that genuine higher order functioning was evident, it is contended that within the *extended* conversations held during this study, with the mediation of signs such as speech and drawing, some movement towards higher levels of thinking (the process of development) was apparent in some children. Significantly, allowing children time to think and to wander around the topic is useful in revealing how their thinking is evolving.

Mentioned in the previous section were the planning and/or problem solving functions that egocentric speech can demonstrate. An example of this involves Ollie and his drawing of sunset, where he speaks largely to himself:

I need... Well, I could tell you something... Silver and blue. (Takes out blue and grey texta) Well, actually I would need **black**. (Takes out black)... Black. Yes, for nights... The sun would have to be dark (Takes out yellow texta). And now... I would... where's the other colours I could use? 'Cos, actually... there's only... one other colour I need... A sunset one. And it's only orange! (Takes out orange texta)... 'Cos orange can **be** a sunset... And I'll need **dark** green... for the grass... all these. You always need the dark green for the grass, at night... (Takes out green). (Ollie, 5.6).

Here, Ollie is formulating a plan of what he intends to draw directly before he commences. In doing this, he is moving beyond merely accompanying the drawing with speech, but anticipating what it will incur and even engaging in simple problem solving. As much of this section of his conversation is directed towards himself, there is an indication that his thinking is moving towards an intermental level. Vygotsky (1999) contended that, with the planning aid of speech, the child's thinking moves beyond the present (as was apparent at the beginning of the conversation with Ollie and the commencement of his drawing) to the future, and behaviour and thinking is reconstructed in a radically new way. As Ollie demonstrated, he has now become able to control or direct his own behaviour. Thinking has been transformed from the 'here and now' to include future actions and possible ways of solving problems.

The link that Vygotsky (1997) saw between gesture, drawing and thinking was also noted within this study. Children, especially within the early childhood and preschool years, may indicate by gesture what they are thinking about or intend to draw, and then repeat that gesture in their drawings. An example is Uma's gesturing accompanying her description about what she was going to draw, which is then replicated in her drawing:

Lightning! I'm going to draw some lightning! (Draws a zigzag line in the air with a finger)... *'Cos there are lightning... And thunder. Boom! Boom! Boom!* (Draws zigzag lines in the air, then on the paper) *I'm gonna write 'boom, boom, boom'...* (Goes back to black cloud she is drawing)... *When's this cloud gonna stop it?... There! Now, ummm... there's just a cloud... 'cos I'm gonna draw a thunder storm! Big thunder storm! Boom! Boom! Boom!* (Bangs texta on table and makes an explosive sound)... *Big boom, boom, boom, boom, boom! Lightning crashing! Boom, boom, crash! Boom, boom, crash! Boom, boom, crash!...* (Vigorously colours in black cloud, banging her texta as she does so) (Uma, 6.5).

With this gesturing and repeated action in the drawing we can again see the beginning of a planning function in activity – an indicator that Uma's mental functioning is moving towards a higher level.

Other instances where, for some children, thinking appeared to be transforming centred on their use of memory. In the early stages of each of the conversations it was quite clear that the children were using direct remembering, recalling the concepts and ideas from shared family understandings, as well as their previous experiences of the rain and the sun. It could be argued, however, that with the addition of drawing into the research activity, for *some* children, their thinking moved more toward mediated remembering. An example of this could be said to be that of Charlie (7.3), where in one extended conversation his initial fairly simplistic comments about

the moon, with the addition of drawing change in character, and his remembering becomes more complex as he recalls what he has observed in terms of the moon and tides. Beginning the conversation with relatively low level comments such as *'The moon goes over the sun'*, *'The moon comes out from the clouds'*, and *'The moon stays there for 8 hours'*, after he begins drawing his thinking appears to be moving towards a higher level. *'We have to do the moon! Full moon!so the waves go up...'*, *'Well, when the full...full moon's out the tide gets really big, and starts to, um, make a big swishing noise'* and *'...But...the water doesn't go that high...It's a half of...half of...'* That is, with the aid of drawing his thinking gradually becomes more elaborate and divergent, and he begins to consider his observations of wider phenomenological concepts such as the relationship between the moon and the tides. Here his mediated remembering is making new connections and more well developed forms of thinking.

Discussion

The method used through this study, with its two-levels of analysis – using Rogoff's three foci and aspects of Vygotsky's ideas – provides a useful way for considering how young children's ideas about the world develop, and reveals that their thinking is often complex and powerful.

A major implication for this form of research with young children involves considering issues of time. Time is needed before the data generation begins not only to establish quality relationships with the participants, but also to understand something of the context/s in which the research is taking place – and its goals for children, beliefs, values, history, and so on. Within the data generation period, if children's views are being sought, time is needed to allow their thinking to meander around topics, and evolve. Recognition of the fact that they may hold multiple views at one time should also be given. Thus it is necessary to attend to far more than the first response a child gives to a particular question, or to focus only on what it is 'expected' they will say or look for the presence or absence only of accepted Western-world scientific concepts. This requires a degree of open-mindedness on the part of the researcher. Reflection, therefore, on how the researcher is mediating the research activity is very important.

In addition, the provision of a number of appropriate cultural tools for children to use during the data generation phase not only supports the development of thinking, but can reveal higher levels of cognitive functioning than unmediated conversation or questioning. Whereas drawing, and for some children singing, were very effective within this particular study, there may be many other tools that help to mediate thinking in other contexts.

Many researchers and academics have reported on challenges associated with changing children's existing views of the world (see, for example, Tytler & Peterson, 2000). While much has been written about taking children's prior learning into account in teaching, within the conceptual change studies so common in science education research (see, for example, Vosniadou & Brewer, 1992; Hodson, 1998; Tytler & Peterson, 2000) most researchers have focused on what occurs inside the classroom. Some authors have suggested reflecting on factors beyond merely cognitive maturity, proposing that issues such as affective and motivational states also need consideration (see, Tytler & Peterson, 2005). However, these assertions appear to be limited to factors that occur *within the child* or *within the classroom*, with some attention to *their effect on* conceptual change. Yet, thinking is embedded in sociocultural contexts, and reflects local

experiences, practices, beliefs, values and goals, and therefore broader issues need to be addressed

Lemke (2001) has argued that science teaching and research has tended to ignore the experiential perspective of the child, who

spends most of every day, before and after science class, in other subject-area classes, in social interactions in school but outside the curriculum, and in life outside school. We have imagined that the few minutes of the science lesson somehow create an isolated and nearly autonomous learning universe, ignoring the sociocultural reality that students' beliefs, attitudes, values, and personal identities – all of which are critical to their achievement in science learning – are formed along trajectories that pass briefly through our classes (Lemke, 2001: 305).

Teaching and learning may be more effective when (similarly to research) recognition of the meandering, evolving nature of children's thinking is given, and to the fact that they may hold multiple views at one time. Consideration should thus be given to programming longer teaching timeframes than is often presently employed. A two week focus (or month-long or even term-long) on the day/night cycle or on evaporation may be grossly insufficient. While it is acknowledged that this presents difficulties for many teachers who already feel that there is not enough time for teaching in the manner that they would like, unless teaching methods are effective then our children may really only be practising 'remembering things', rather than learning for understanding and application. Indeed, studies such as that conducted by Kikas (1998) indicate that while children may 'remember' concepts taught two months earlier, four years later the information was not retained – nor, one could argue, had it been effectively understood.

Continued reflection is needed on the place of cultural tools within learning. While teachers frequently consider what physical teaching aids or models they may incorporate into their lessons, attention should also be paid to the extent to which the artefacts they use match the particular cultural tools of the community (as opposed to the teacher selected artefacts of a typical classroom). These tools may include more use of things such as singing, drawing, dramatising, or using many of the 'hundred languages' of childhood (Edwards, Gandini & Forman, 1998).

Conclusion

Much of the previous research explains children's conceptualisations as being determined by particular mental structures which grow and change during the course of a child's development. Children are said to develop hierarchical, internally consistent mental models which emerge out of experience and acquired knowledge. In contrast to considering the development of thinking from a Piagetian framework, this study, focusing on children's extended conversations about various natural phenomena, has highlighted aspects often ignored in more traditional research, such as the intermental to intramental nature of thinking, and how conceptualisations are mediated through collaboration with others (both proximally and distally) and by particular signs and cultural tools. Consideration was given also to the role of the

researcher within the research activity, and time was allowed for thinking to evolve and to wander around the topic.

The analysis, using the two pillars of Rogoff's three foci of analysis (contextual/community, interpersonal and personal) followed by reflection on aspects of Vygotsky's theorising provides an innovative way for considering how children's ideas about the world develop. What was revealed is that their thinking is often far more complex, rich, powerful and dynamic than traditional research methods demonstrate. Importantly, too, it indicates that consideration of the social/cultural/historical line of development as well as the natural or biological line of development is necessary if we are to gain an authentic understanding of how young children's ideas about the world are formed.

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