Analysing young children's thinking about natural phenomena: A sociocultural/cultural historical perspective

Jill Robbins

Faculty of Education
Monash University
Australia
jill.robbins@education.monash.edu.au

Abstract

Vygotsky's sociocultural/cultural historical theory emphasised the notion of semiotic mediation – or how thinking is transformed through signs (such as language) and cultural tools (such as drawings) from an intermental to an intramental plane. While the ideas of Vygotsky have become well-accepted within research in early childhood education in Australia, they are somewhat slower to be adopted within science education research. Yet they offer the potential for gaining new understandings of how young children's thinking about the world develops. This article will demonstrate one way in which aspects of Vygotsky's (1987-1999) work, particularly his ideas about semiotic mediation can inform analysis of children's thinking about the world. Focusing on conversations with children about natural phenomena, and drawings they completed during those conversations, the analysis identifies a number of significant issues that are not normally revealed within the dominant forms of analysis which draw on constructivist perspectives. The findings, which reveal complex and dynamic aspects of children's thinking, have implications for both teachers and researchers working with young children – especially within science education and science education research.

Key Words

Young children's thinking, sociocultural/cultural-historical theory, methodology, early childhood science

Résumé

La théorie socioculturelle/culturelle-historique de Vygotsky a mis l'accent sur la notion de la médiation sémiotique; c'est-à-dire à la transformation de la pensée par des signes (par exemple, le langage) et par les instruments culturels (par exemple, le dessin) se changeant du niveau inter-mental au niveau intra-mental. En Australie, les idées de Vygotsky ont gagné du terrain dans le domaine de la recherche de la petite enfance; cependant, dans la recherche de l'éducation scientifique n'ont pas encore pris un grand essor. Néanmoins, ces idées offrent des possibilités pour acquérir des compréhensions nouvelles concernant la manière à penser des enfants sur le monde qui les entoure. Cet article se concentre sur la démonstration des aspects de la recherche de Vygotsky (1987-1999); en particulier, les idées de Vygotsky sur la médiation sémiotique peuvent nous renseigner sur l'analyse de la pensée des enfants sur le monde. L'article met l'accent sur les conversations avec des enfants sur les phénomènes naturels et les dessins que les enfants ont produits pendant ces conversations. L'analyse identifie un nombre des issues significatives; normalement, ces issues ne sont pas révélées quand on fait des analyses d'un point de vue constructiviste. Les conclusions ont surtout des implications pour les chercheurs de l'éducation scientifique et pour les professeurs des sciences s'occupant des petits enfants. De plus, les conclusions révèlent des aspects complexes et dynamiques de la pensée enfantine.

Mots Clés

Pensée des jeunes enfants, théorie socioculturelle/culturelle-historique, méthodologie, sciences dans la petite enfance

Introduction

The Russian psychologist, Lev Vygotsky, who died a premature death in 1934, has been described as a profoundly original thinker (Bakhurst, 2007), and a man ahead of his time (Vygodskaya, 1995). It is without doubt that the ideas he developed in the 1920s and particularly the early 1930s have, in the last fifteen or twenty years, gained increasing interest in many disciplines, including education. A key principle of his work is that thinking must be understood as the emergent outcome of cultural-historical factors, and that learning and development are mediated processes (Daniels, Cole & Wertsch, 2007). Complex though his ideas are, there is much they have to offer today to those who are researching the development of children's thinking and their conceptualisations of the world – especially within science education research. His theory provides

a contrast to that of his one-time contemporary, Jean Piaget, and other constructivists whose work often informs research and teaching within science education. These theorists and academics often explain young children's thinking in terms of the particular *mental schemes* (Piaget, 1972, 1973) or *mental models* (Samarapungavan, Vosniadou & Brewer, 1996; Vosniadou & Brewer, 1992, 1994; Vosniadou, Skopeliti & Ikospentaki, 2004) they have developed. Young children are frequently said to hold conceptualisations about the world that are *alternative*, *naïve*, *intuitive* or *untutored* (see, for example, Driver, 1981; Henriques, 2002; Pfundt & Duit, 1994; Siegal, Butterworth & Newcombe, 2004). What is highlighted is that which is said to be 'lacking' in their thinking, and the concepts that need to be 'corrected' through teaching processes such as those adopted by the conceptual change movement (see, for example, Carey, 1985; Duit & Treagust, 2003; Opfer & Siegler, 2004; Tytler, 2002; Watson, 1997).

While much of the previous body of research in science education has been useful in helping us understand how children come to know the world, increasingly the assumptions, theoretical bases and methodological principles on which these studies are conducted are being examined. First, for example, the concept of *individual views of learning* such as that which has its origins in Piaget's work, and is frequently the assumption in conceptual change theories, has been questioned by authors such as Leach and Scott (2003). Second, the notion of the universality of childhood (such as is implied within constructivist theories of learning) is progressively being interrogated (see, for example, Göncü, Tuermer, Jain, & Johnson, 1999; Rogoff, 2003; Woodhead, 2000). Third, some query whether children's views are really 'alternative', asking 'Alternative to what?' (Fleer, 1999). Finally, the apparent ease with which young children's thinking (or thinking at one particular point in time) can be 'boxed' or labelled has been challenged (see Robbins, 2005).

Although there is a move away from the idea of viewing learning solely in terms of cognitive processes in the individual, towards a consideration of students as they function in social contexts (Leach & Scott, 2003), the focus still remains on *individuals*, with the physical and social contexts being seen as 'add-ons' which 'influence' the mental models that children develop. In thinking about teaching and learning attention is given to how teachers can transfer a body of knowledge to individuals, and can rectify the alternative conceptions they hold. Given what is known about learning from constructivist or conceptual change perspectives, academics then often wonder why children can fail to engage with science and why the alternative conceptions remain.

Clearly it is useful to know about characteristic ways that children may think, such as outlined in Piaget's stages of cognitive development. However, *sociocultural views on learning* (Leach & Scott, 2003), and particularly the work of Vygotsky (for whom both the cultural *and* biological aspects of development were seen as important), can present us with another view on how children learn. From this perspective, higher mental

functioning and learning about the world are derived from the social, cultural and historical contexts in which children live. Rather than focusing mainly on what is occurring inside children's heads, sociocultural researchers direct their attention to the types of experiences children have in their world, the kinds of things that are valued, supported and talked about within their environments, the artefacts and cultural tools which are commonly used, and the beliefs, practices, customs and 'ways of doing things' of their communities. Teaching is concerned with how scientific ideas are internalised and transformed or appropriated by children and become useful to them. Further, there is a consideration of how the everyday concepts that children develop through their experience with the world and the scientific concepts they encounter in school can *come together in meaningful ways* - rather than the everyday simply being replaced by academic concepts.

Currently, there are a relatively small, but growing, number of science education researchers who are framing their work from a sociocultural or cultural-historical perspective (see Fleer, 2009; Fleer, Ridgway & Gunstone, 2006; Fleer & Robbins, 2003; Giest & Lompscher, 2003; Leach & Scott, 2003; Lemke, 2001; O'Loughlin, 1992; Schoultz, Säljö and Wyndhamn, 2001; Traianou, 2006). At the same time, the application of cultural-historical/sociocultural theory is an increasing trend in *early childhood* education research. Consequently, for many in early childhood education there is a movement towards sociocultural views on learning, while science education appears largely fixed on individual views of learning.

RESEARCH FOCUS

This article argues that a Vygotskian informed (Vygotsky, 1987, 1997, 1998, 1999) *sociocultural/cultural-historical* approach to science education research has the potential for gaining new understandings of how young children's thinking about the world develops. It draws on a study which has attempted to identify some socioculturally-informed methodological principles and conceptual tools that may assist in the data generation and analysis of young children's understandings of natural phenomena. A conceptual tool can be described as something which is intangible. It is a scheme which frames thinking, and allows one to enact one's ideas. In this particular study Rogoff's (2003) three foci and aspects of Vygotskian theorising were the selected conceptual tools, and resulted in highlighting 'new', more positive insights into young children's thinking about the world.

The research took place in two preschool classes and three junior primary classes within an independent school situated in the outer South-eastern suburbs of Melbourne. The fifty-seven participants (24 girls, 33 boys) spread across these classes ranged in age from three to eight years of age. Data was generated in extended open-

ended conversations (most around half an hour in length, though some considerably longer) about the sun at night and how rain happens. As the children talked they were invited to draw, with the view that this might help to mediate thinking. Two rounds of conversations were conducted, twelve months apart.

However, when it came to implementing a sociocultural analysis, a number of challenges arose – principally concerning how a Vygotskian perspective could be applied to the process. While Vygotsky's writings, particularly his collected works, provide complex and detailed descriptions of his theorising, there seemed to be no clear set of guidelines that could be directly transferred to the study. In addition, the process of intermental to intramental functioning (explained below) could not be analysed without gaining some comprehension of significant others both at a proximal and distal level with whom the children might hold some shared understandings. Issues such as semiotic mediation (again, explained below) could not be analysed, without first identifying important signs and tools. Consequently, a decision was made to analyse the data on two levels – firstly using Rogoff's (2003) three foci of analysis to highlight certain factors that appeared to be mediating thinking, followed by a deeper analysis from a Vygotskian perspective.

Theoretical Informants for the Study

Rogoff's three foci

As outlined in previous work by this author (Robbins, 2005, 2006), from a sociocultural perspective, Rogoff's (1998, 2003) three foci of analysis (derived from the ideas of Vygotsky and other sociocultural/cultural historical theorists) provide a useful conceptual tool for analysis in research with young children. Within this approach there can variously be a highlighting of the participation of a child within an activity and how this participation changes or transforms during the course of the activity (personal focus of analysis), children's relationships and collaboration with others (interpersonal focus of analysis), and on contextual, cultural, institutional and historical factors (contextual or cultural-institutional focus of analysis), *with anyone of these being in focus while the others remain in the background.* One cannot interpret any one of these foci of analysis without seeing how it fits into the ongoing activity.

In contrasting with dominant research methods, particularly in science education research, instead of examining small extracts of conversation (or more commonly interviews) with decontextualised individuals, the three foci offer the potential for analysing the multiple factors, beyond mental schemes or mental models, that are constituted with thinking. These can include understandings that children *share* with significant others such as extended family members and friends - as opposed to those which are supposedly individual views. Values, beliefs, and cultural histories and prac-

tices can be considered, along with various signs and tools or artefacts that mediate thinking. Importantly it affords the examination of the role of researcher within the data generation process, and the extent to which this may support or even hinder thinking.

This conceptual tool does not give priority to ideas learned in school, but gives equal attention to what is learned at home or in other community settings. There are no presumptions about development, so it is less likely that children will be positioned as deficient in thinking. In fact, it can present a very positive view of their conceptualisations, as the analysis is not limited by looking for certain pre-determined categories of thinking. Therefore, it affords the highlighting of the dynamic and often powerful characteristics of their ideas.

Yet, while the foci examine personal, interpersonal and cultural factors constituted with thinking, they do not necessarily adequately consider or explain psychological processes. However, they do serve to bring to the foreground a number of issues which can then be more easily analysed from a Vygotskian perspective.

Vygotsky's theorising

Without a doubt, Vygotsky's theorising provides a compelling way of understanding qualitative changes that occur, across time, in children's thinking. This occurs through a number of complex, inter-related processes.

Intermental to intramental functioning

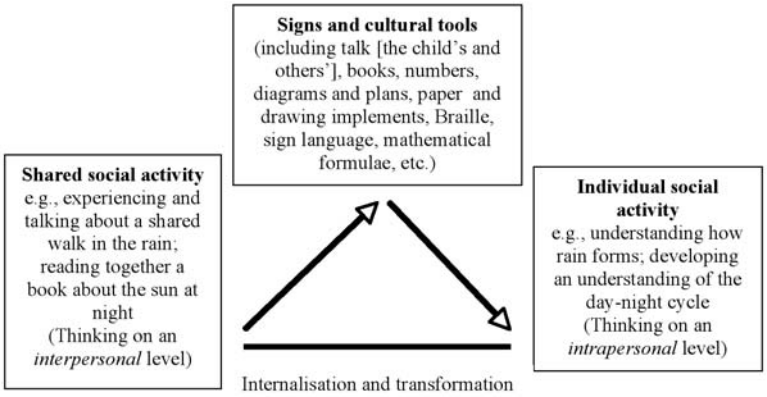
A key tenet of Vygotsky's ideas is that learning (and thinking) occurs first on an intermental level, between a person and other people engaged in joint sociocultural activity. This shared thinking is gradually internalised and transformed on an intramental level (Vygotsky, 1987, 1997, 1999). As Vygotsky (1997, p.105) said, 'through others we become ourselves'. However, it is not merely the interaction, per se, between people that brings about cognitive development. This occurs through the mastery and appropriation of signs and tools – through semiotic mediation.

Semiotic mediation

Mediation is an important theme in much of Vygotsky's work. This concept suggests that, instead of acting directly on the social and physical worlds (as Piaget suggested), our contact with the world is indirect or mediated by signs, symbol systems and tools (Wertsch, 2007). That is, Vygotsky (1987, 1999) contended that it is through children's mastery of speech and other signs and symbol systems (such as writing, drawing, number and counting systems, Braille, sign language, scientific and mathematical formulae, diagrams, mnemonic aids) that they come to know the world (see Figure 1). Signs perform an important role in meaning-making, and in directing attention, shaping memo-

ry, developing active control over one's own thinking and acting, and gradually establishing other higher forms of mental functioning. Further, as signs bring a cultural heritage and history with them, by learning to use these symbol systems, people integrate and draw on the experiences and understandings of others in previous times and places (Vygotsky, 1987, 1997).

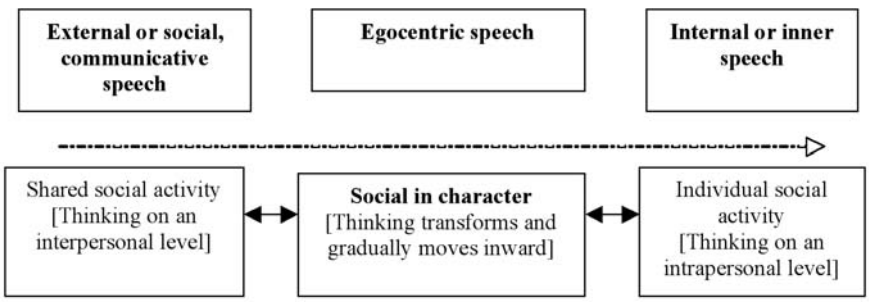
FIGURE 1



Semiotic mediation. Shared social activity and meaning is internalised through the use of signs and cultural tools, gradually becoming transformed into individual thinking

For Vygotsky (1987, 1999), speech (talk) holds the foremost role in the mediation of thinking, and follows a particular developmental path from external or social speech (thinking at an intermental level), to egocentric speech or speech for oneself, to inner speech (thinking at an intramental level) (see Figure 2).

FIGURE 2



Vygotsky's view of the development of external to internal speech. Egocentric speech serves as an important intermediary between social and inner speech, and thus helps transform thinking

Vygotsky (1987) contended that egocentric speech performs a vital intellectual function, in that it forms an important intermediary between the social and the individual, or external speech and inner speech. After a period of being dependent on the speech of others (social speech) to guide actions, solve difficult problems, and regulate behaviour, children gradually develop the ability to carry out activities guided by their own speech – initially egocentric speech, and then inner speech. Egocentric speech can be an indicator that children's thinking is becoming internalised and is transforming, and therefore can be a gauge of a child's developing cognitive maturity. Vygotsky (1987) argued that this view contrasts with that of Piaget who saw egocentric speech as having no useful function in the development of thinking, being a symptom of the weakness or immaturity of young children's thinking, which would eventually disappear as they grow older.

Though he believed that speech is the most important sign or semiotic mediator, Vygotsky (1997, 1998, 1999) also paid special attention to a number of other signs and tools, including gesture and drawing, and their relationship with higher mental functioning, as discussed in this next section.

Lower to higher mental functioning

At birth children possess a range of lower order mental processes, such as elementary attention, involuntary perception and lower order memory. Over time, through the mediation of signs and other symbol systems, these processes are progressively transformed into (rather than being replaced by) complex, inter-related higher mental functions. Through speech (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, planning, problem-solving and other forms of goal-directed thought and activity. Each higher function, though, has its own specific course of development, but in coming together, they become very powerful. This gradual restructuring begins in the preschool years and continues through the primary school years.

As an example, Vygotsky (1998, 1999) contended that when children are drawing, speech is initially likely to accompany or follow their actions. That is, at first children will simply draw and then name parts of their drawing, or they will describe the actions they have used in their drawing ('These are arms'; 'I've made some lines'; 'There's lots of dots'). Here they are demonstrating elementary attention and lower order perception. Gradually, however, the naming of the drawing will shift to the commencement of the process, and the intention of the drawing will be announced ('I'm going to draw a…'). From this point on, speech increasingly serves a planning and directing function, moving to the egocentric and eventually intramental, inner speech level. There has been a gradual restructuring to higher psychological processes (Vygotsky, 1987, 1998, 1999).

For Vygotsky (1997), drawing, writing, gesture and thinking are all linked, and '[w]hen the child draws, he (sic) very often makes a transition to dramatization, showing by gesture what he wants to picture, and the line made by the pencil only supplements what has been depicted in the gesture' (p.134). That is, Vygotsky believed that children, especially within the early childhood and preschool years, will sometimes indicate by gesture what they are thinking about or intending to draw. With this gesturing and subsequent action in the drawing a planning and problem solving nature to thinking becomes evident. This is a significant indication that mental functioning is beginning to move towards a higher level.

The development of memory was another aspect of higher order thinking which was of particular interest to Vygotsky. He claimed that memory is among the most central and basic of mental functions for young children, and that the development of other processes, reflects a dependence on memory. 'For the young child, to think means to remember, to rely on his (sic) previous experience and on the modification of this experience' (Vygotsky, 1987, p.308). He explained that in the early stages of development, it is children's direct experiences, and their memory of those experiences, that define the structure of thinking. For example, in explaining what a snail is a young child is likely to define it in terms of recalling the direct experiences: small, slippery and moves with its foot, or other condensed summary of the memories of the snail.

In contrast to this innate or direct remembering (commonly used in early childhood) is a cultural form of remembering, defined as mediated remembering. This entails the introduction or creation of some device or tool for remembering – such as tying a knot, as a crude example (Vygotsky 1997). In effect, with mediated remembering a mnemotechnical sign is inserted between the event or object and the structure of memory, and a new way of remembering forms. That is, new associations or connections occur with mediated remembering, and logical relationships are established, thus moving towards higher order functioning (Vygotsky, 1987, 1997).

The gradual development of higher forms of thinking, be it logical memory, deliberate perception, planning, or voluntary attention, are also closely linked with voluntary control in academic thinking, and particularly the development of scientific concepts.

Everyday and scientific concepts

Everyday concepts refer to those ideas acquired by children usually through social interaction with adults (through intermental functioning) and/or through practical experience of the world. They are used to denote or signify objects, and take their meaning from perceptual, functional or contextual factors. However they are not integrated into a broader structure or *system* of concepts. Further, children are not conscious of their act of thought in using them (Panofsky, John-Steiner & Blackwell,

1990). For example, a young child may hold an everyday concept of the sun as 'a ball of fire in the sky' or 'something which is warm, and brings the light and makes me feel happy'.

Vygotsky (1987) used the term scientific (or academic) concepts to refer to concepts that have explicitly been introduced through instruction, generally in school. An example is an understanding of the relationships between the sun within our solar system and the eight planets and large number of smaller objects. They are referred to as *scientific* 'not because their contents are scientific, but because they are systematically learned' (Haenen, Schrijnemakers & Stufkens, 2003, p.250). Scientific concepts exist within a hierarchical network of connected or inter-related concepts. They are used consciously and intentionally by people, but are generally removed from concrete experience. Importantly, scientific concepts develop *along* with maturing mental functions, such as conscious awareness, logical memory, organisation, problem solving, and so on (Vygotsky, 1987).

However, Vygotsky emphasised that the two types of concepts are closely connected and continuously influence each other. Both are important. Genuine mature conceptual development is based on the *combined* strengths of everyday and scientific concepts. That is, children should be able to give the formal definition of a concept and point out its link with other related concepts, and their understanding of such a concept should reflect current scientific understanding (scientific concept). Moreover, the concept should come to life for children through them being able to make some link with their everyday understanding of the subject (everyday concept).

Examples of the significance of these foregoing issues in data analysis are given and explained in the following section.

Analysis

The analyses of the conversations, described earlier (see Research Focus), highlighted a range of factors associated with the origin and development of children's thinking, beyond merely the mental schemes or mental models that are reported in dominant forms of research.

Rogoff's three foci as an analytical tool

Rogoff's three foci powerfully highlighted the *mediated* nature of thinking. The children demonstrated that they held many understandings of the world, as well as beliefs, values and cultural histories, that were shared with significant others in their lives, such as parents, siblings, grandparents – as well as those within their school and other institutions. It was also obvious that various cultural tools were mediating their thinking, or had done so in the past. These included things such as the drawings they engaged

in as we spoke, songs that a number of the children spontaneously broke into, as well as books they had read and television programs or DVDs they had viewed at other times and places.

In addition, it became evident that, instead of being deficient, their thinking was often rich and purposeful (see Robbins, 2005, 2006). Further, there was a dynamic and evolving nature to this thinking. Significantly, many of the children appeared to hold multiple (and sometimes conflicting views) at the same time. This was often apparent when children engaged in egocentric speech as they drew - and indicates that in order to uncover the complexity of their ideas, there is a need for providing specific cultural tools (such as felt-tipped pens and paper) and for allowing time in research activities with children for their thinking to meander around a topic.

Importantly, the three foci afforded reflection on the historical 'ways of doing things' in research, and the role of the researcher in the activity. Such things as the values, beliefs and actions of the researcher were examined, and how these, too, mediate (or at times hinder) children's thinking.

However, while these foci, as a conceptual tool, highlighted a significant number of personal, interpersonal and cultural/contextual issues, they were not adequately able to address or explain *psychological* processes of thinking. It is for this reason that a further level of analysis was necessary, and Vygotskian theory provided the conceptual tool for this deeper level of analysis.

Vygotskian theory as an analytical tool

This level of analysis revealed evidence of intramental to intermental thinking, semiotic mediation, some movement towards higher mental functioning, and an overwhelming presence of everyday concepts. There was less indication of scientific or academic concepts – despite the fact that the older children had been in school for nearly four years and had received some formal teaching in Earth and Space Sciences, such as weather, the day and night sky, and the sun and moon. Some of the factors that came to light are outlined in Table 1.

The scope of this present article does not permit discussion of all these factors. Therefore, a small number of what I believe to be significant inter-related signs and tools, or semiotic mediators, and psychological processes will be considered further. These are egocentric speech and gestures and how these, in combination with drawing, can be indicators of movement towards higher order thinking. The relationship between the development of scientific concepts and higher order functions will also be briefly discussed.

TABLE 1

Issues related to aspects of Vygotsky's theorising that were evident in the study.

Vygotskian concept	*Factors highlighted from the data*
Intermental to intramental functioning *Learning occurs first between people. It is then gradually internalised or appropriated on an individual plane.*	• The children in this study commonly expressed ideas, beliefs and concepts they shared with important others within their community groups – e.g., parents, grandparents, and siblings. • There was some evidence (often through egocentric speech) to suggest some children were attempting to internalise and reflect on these ideas, and make them their own. • There was less evidence that children held ideas that appeared to be derived from the social world of school. Where there was, it was apparent children often held multiple (and sometimes conflicting) views and were struggling to make sense of these ideas.
Semiotic mediation – Mediation of thinking by signs and tools *Cognitive development occurs through a child's mastery, appropriation and internalisation of signs and tools.*	• Within this study, speech (social speech and egocentric speech) was an important mediator of thinking, both at the intermental level and in the transformation of thinking to an intramental level. Inference could also be made at times of the role of internal speech in mediation. This was particularly significant when time was allowed for the conversation to meander or wander around the topics. • Speech brought the ideas of others, the 'voice' of others, and collective rememberings to the present situation. • For the children in this study drawing appeared to be a powerful mediator of thinking, especially within a relaxed time frame. • Gesturing, for some, was also a significant mediator, as perhaps was singing. • There was also indirect evidence of some mediation occurring through television programs and books.
Movement towards higher mental functioning *It is through the use of signs and tools that lower mental functions or elementary processes with which children are born gradually are transformed through countless stages to complex, interrelated higher forms of mental functioning*	• Movement from lower to higher order mental functioning occurs over a long time period. • In this study some movement towards higher order thinking was evident when the speech of some children moved from accompanying their drawing, to the beginning of the drawing process, and assumed a planning function. • Movement towards higher order functioning was inferred from the focused attention of some children while drawing. This was, at times, accompanied by egocentric speech, often assuming a planning nature. • Conscious efforts to indicate the connections between objects in drawings were made by some of the older children, with arrows signifying correlations, links and paths of movement appearing. This indicated conscious awareness and deliberate attention, with some possible movement from thinking in everyday concepts towards the development of scientific concepts. • In a few cases, children used gesture to indicate what they intended to draw, then repeated that gesture in their drawing. This could possibly represent some movement towards controlling thinking and planning of actions. • Mediated remembering (e.g., where drawing or singing was mediating remembering) was also evident in some instances. Verbal prompts also mediated remembering.

TABLE 1

Issues related to aspects of Vygotsky's theorising that were evident in the study.

Vygotskian concept	*Factors highlighted from the data*
	• There was some evidence of reflection on thinking (see second point in intermental to intramental functioning) as children were attempting to make ideas conveyed to them by others their own.
Everyday and scientific concepts *Everyday or spontaneous concepts are acquired by the child, usually through social interaction with adults and/or through practical experience in the* community. *Conscious awareness absent. Scientific or academic concepts are concepts that have explicitly been introduced through instruction in school, and depend on the presence of conscious awareness.*	• The children in this study held rich everyday concepts, gained primarily through interactions with family members and through direct experience. • There was less evidence of scientific concepts related to the topics of the study. • Though there was some intentionality evident in some children's use of concepts, they often appeared to be struggling to make sense of the multiple concepts they had acquired (either through direct experience, from family members, or had been taught by teachers). • It could be inferred, therefore, that as Vygotsky described, scientific concepts may take a long time to develop, and may depend upon more evidence of the development of higher order thinking processes.

DISCUSSION

Though the course of development of higher mental functioning takes years to be realised, and it is not suggested that genuine higher order functioning was evident, it is contended that, within the *extended* conversations of the research study, with the mediation of signs such as speech (egocentric, social and inner) and gestures and drawing, some movement towards higher levels of thinking was evident in some children. Allowing children time to think and to wander around the topic was useful in revealing how their thinking was evolving.

Egocentric speech

As stated earlier, for Vygotsky (1987, 1999), egocentric speech has an important intellectual function. It forms an important intermediary between the social and the individual, or external speech and inner speech, and is an indication of the child's developing cognitive maturity. Egocentric speech is not simply speech that *accompanies* a child's action, but frequently assumes a planning and/or problem solving function. In the study, this was evident when children talked to themselves about what they are going to do or how they would tackle a challenge.

An example of this involves an extract of Ollie's (5.6) conversation (Table 2, below) about the sun at night, specifically while he was engaged in drawing the sunset. Although there were a few minor comments and 'encouraging' words from me (JR) interspersed with his speech, Ollie appears largely unaware of me as he engages in his

TABLE 2

Extract of a conversation with Ollie (5 years and 6 months) in which egocentric speech is assuming a planning and problem-solving function. His attention is largely focused on his thinking and drawing

34	Ollie	I need…Well, I could tell you something…Silver and blue. (takes out blue and grey textas) Well, actually I would need **black**. (Takes out black)
35	*JR*	*Okay. Yep.*
36	Ollie	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)
37	*JR*	*Mm-huh.*
38	Ollie	'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)
39	*JR*	*…Okay. Now, which one would you like to start with, and I'll take the top off for you.*
40	Ollie	Okay. Now, let's think…
41	*JR*	*Remember you're drawing me a picture of what happens to the sun at night time.*
42	Ollie	(Appears to say the following to self)…Need…I must…What happens...if the sun could do it? How come the moon happens to…?
43	*JR*	*How come…?*
44	Ollie	(No reply)
45	*JR*	*Which colour would you like to start with?*
46	Ollie	Now, let's see…So, I'll have to start, I could do 'eenie, meenie, miney, mo' (touching textas as he says this)
47	*JR*	*You could.*
48	Ollie	…Eenie, meenie, miney, mo. (Touches each texta in turn). Orange. And orange is for the sunset, usually. And before that…is…and I wouldn't need the black, because do you know…? But I can do it on the **ba-ack**, so I can show you what happens… **I** know! Can do it on another page. And this. Morning. (Touches paper in front of him). Then sunset. (Touches table to indicate his intention to do another drawing, this time of sunset) And then…dark!
49	*JR*	*What a great idea!*
50	Ollie	So I…
51	*JR*	*Terrific!*
52	Ollie	So, I've got this to do there…
53	JR	*Okay. That sounds terrific!*
54	Ollie	Now, it's…(picks up orange)
55	*JR*	*Shall I take the top off for you?*
56	Ollie	Yes.
57	*JR*	*(Takes off the orange top) There you go.*
58	Ollie	I'll have to make it…and not…I have to always make this...the sun…look orange (Begins drawing vigorously with orange)…Sound of it (The texta is quite audible as he draws)…Now…I would need the sunlight. I would need the sun…coming down. (From this point on Ollie is very involved in his drawing, though he talks to me and himself frequently, often without looking up)
59	*JR*	*Okay. (Replaces orange top for him)*
60	Ollie	…And it would come from the east. It will come down from the **west**. What **I** need to do is make a little…sun (picking up yellow texta) so it can be far from the west.
61	*JR*	*Okay. (Takes top off yellow texta)*
62	Ollie	That's why it's to the east. (Draws a yellow circle at the bottom left)…That's what I have to do when I make all this (Adds 'rays' to the circle)…All this…So it's in the west…It's about to come down…Isn't it?

drawing and thinking. His attention is directed largely at what he is drawing and thinking. Further, the syntax of his egocentric speech has changed from that of the social speech he has engaged in at the start of our conversation. Instead of complete sentences, his speech has changed into abbreviated sentences and words, not really suitable for communicating with others but sufficient for communicating with himself (Bodrova & Leong, 2003) (see especially Lines 36 and 58.)

Here, Ollie is formulating a plan of what he intends to draw, directly before he commences. In doing this, his speech is moving beyond merely accompanying the drawing, but anticipating what the drawing will include 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 my 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 is being transformed from the 'here and now' to include future actions and possible ways of solving problems. There has been a gradual restructuring to higher psychological processes (Vygotsky, 1987, 1998, 1999).

In the dominant methods of science education research, little attention appears to be paid to egocentric speech. This is not surprising, given that much of this research is informed by Piagetian or constructivist theorising. From this perspective, egocentric speech is perceived as holding little importance in children's cognitive development, and in fact is regarded as an indicator of cognitive immaturity. It is contended that, in this matter, Vygotskian theory as an informant for research holds the potential for moving our understanding of young children's thinking forward.

Gesture

Earlier it was stated that Vygotsky (1997) believed that children, especially within the early childhood and preschool years, will sometimes indicate by gesture what they are thinking about or intending to draw, and then repeat that gesture in their drawings – a process that was noted within this study. This is graphically illustrated in the following short extract of a conversation with Uma (Table 3) and her drawing (Figure 3), below. Here she uses gesture to indicate the movement of lightning in the first few lines of this extract, then repeats this action in her drawing. Later, while talking about the sound of thunder, she bangs the table with her fibre-tipped pen, and then repeats this forceful movement in her drawing as she colours in the black cloud she has drawn. With this gesturing and repeated action in the drawing a planning and problem solving nature to thinking becomes evident. That is, the gesture is signalling what Uma *intends*

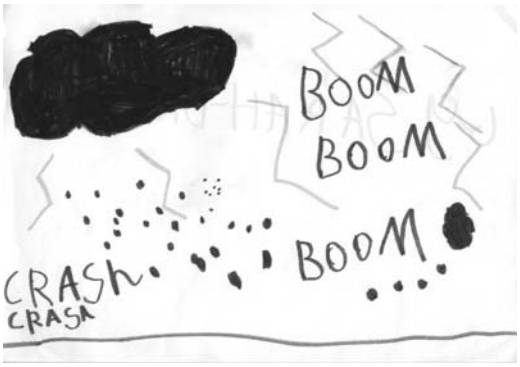
to draw. Again, this is a significant indication that mental functioning is moving towards a higher level.

TABLE 3

Uma (6 years and 7 months) uses gesture to indicate what she will draw, then repeats that gesture in her drawing, following.

774	Uma	Lightning! I'm going to draw some lightning! (Draws a zigzag line in the air with a finger)
775	*JR*	*Okay.*
776	Uma	'Cos there are lightning…And thunder. Boom! Boom! Boom! (Draws zigzag lines lines in the air, then on the paper) I'm gonna write 'boom, boom, boom'.
777	*JR*	*Okay.*
778	Uma	(Goes back to black cloud)…When's this cloud gonna stop it?…There! Now, ummm…there's just a cloud…'cos I'm gonna draw a thunder storm!
779	*JR*	*Okay.*
780	Uma	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)

FIGURE 3



Uma's drawing of how rain happens, in which she replicates in the drawing the gestures she has previously demonstrated in the air and on the table

While in the past, few science education researchers have reported children's use of gestures during interviews, there has been some recent attention given by a number of academics to the role of gesturing in *teaching* and *learning* in science (see, for example, Roth, 2000, 2004; Roth & Welzel, 2001; Roth & Lawless, 2002; Lemke, 2004; Tytler, Prain & Petersen, 2007). Roth and Lawless (2002), for example, emphasise that gestures are a fundamental feature of cognition, and suggest that there is much to be learned about the role of gestures in learning. Roth (2004) believes that in attempting to make scientific explanations, children frequently begin with 'muddled talk' (p.49), and if given lots of time, through gesturing, often end up with feasible ways of speaking and writing about science phenomena. However, these authors tend to suggest that gestures can be useful to help children *represent* their ideas, but unlike Vygotsky do not appear to emphasise a definite link between gestures and movement towards *higher order thinking*.

Drawing

The study indicated that drawing, along with signs such as speech and gesture, appear to be a significant tool or symbol system in mediating thinking. Vygotsky (1998) contended that during the preschool years drawing is frequently directly connected with play, whereby a drawing may include several objects that appear to have little connection to each other. However, gradually the child enters a second stage where drawing becomes more mechanical, external features are drawn in detail, and the connection between separate objects is more complex and elaborate.

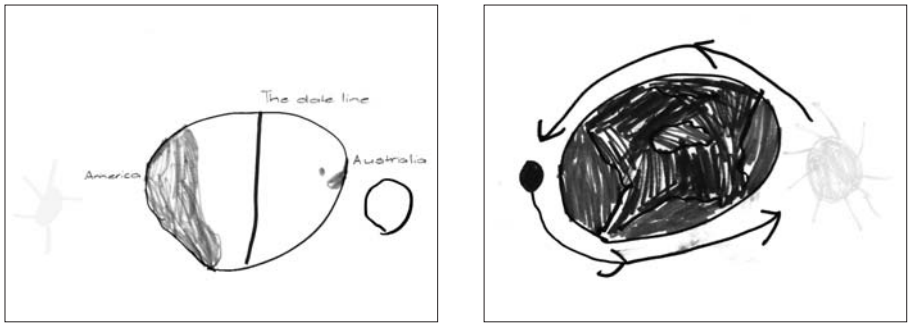
These characteristics were evident within the study, where the drawings of many of the younger children had a playful characteristic about them. Along with the sun and moon or clouds and rain there was often the inclusion of such things as pets, friends, siblings, flowers and birds, as well as some fanciful creatures such as Martians and pirates. Frequently objects in the pictures appeared to be unrelated in any 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 of drawing (ages 9 to 12), made conscious efforts to indicate the connections between objects. Thus, arrows indicating correlations, relationships and paths of movement appeared in the drawings of some of these older children, such as that of Fergus (Figure 4) below.

FIGURE 4

Fergus' (6 years and 11 months) drawing of how rain happens, in which he uses arrows and labelling to demonstrate the relationship he sees between various elements in this process

These arrows and connections were often not present in the first drawings children had completed – some 12 months earlier. Compare, for example, the first drawing completed by Ned (below, left, in Figure 5), with his second one completed a year later (below, right, in Figure 6). In the second drawing there is attempt to indicate some movement of the sun and moon and real connection between the heavenly bodies, rather than the static representations in the first drawing.

FIGURE 5 & 6



Ned's (age n/a) first drawing (the labelling is mine) compared with his second drawing (completed 12 months later) - in which he uses arrows to indicate the path of movement of the sun and the moon.

This, too, is an indicator of a development in thinking, in which there is a movement beyond thinking in isolated complexes and everyday concepts towards more scientific concepts. Ned is beginning to see systematic relationships between various ideas, and is consciously and intentionally attempting to organise these ideas. This tends to suggest that the learning he was engaging in was leading to the development of higher mental functioning, and new ways of thinking - learning leading development.

There were also occasions when drawing appeared to act as a mnemotechnical tool – promoting mediated remembering. That is, with the addition of drawing into the research activity, for *some* children, their thinking moved more towards mediated remembering (where there is the introduction or creation of some device or tool to assist with remembering). An example of this could be said to be that of Charlie, where 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 and begins to establish some logical relationships. 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 transforming to 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, 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. Eventually, during adolescence, there will be a gradual transition from the external mediated remembering, to an internal form of

mediated remembering, a transition which is connected with 'the powerful development of internal speech' (Vygotsky, 1998, p.99).

However, these higher forms of thinking might not have been evident without the extended time frame for the research activities the children engaged in, nor without the availability of the artefacts for drawing. That is, though conversations (or interviews) mediate a certain level of thinking and sharing of ideas, it was conversations *in combination with* time and the artefacts that revealed this development of higher forms of mental functioning.

Relationship between scientific concepts and higher order functioning

What differentiates scientific concepts from everyday concepts is that the latter are spontaneous and do not require conscious acts of thought in their use, while the former are characterised by conscious awareness. Scientific concepts are academically oriented, exist within a system of knowledge (that is, scientific concepts are related to other scientific concepts), and are *used consciously and intentionally* (Vygotsky, 1987).

What was very noticeable in the study was that many of the children held rich everyday concepts, developed through interaction with family members and in some cases their teachers and others at school, and with the environment. While they were vivid and often highly imbued with personal significance, they were generally not integrated into a system of related concepts. Thus most of the children could talk freely about what they had directly observed, experienced or come to believe through family interactions. They appeared far less confident in attempting a scientific explanation – though, for some of the children, there was evidence of *reflection* on thinking. An example is Ollie's mumbled comments to himself as he was drawing, such as '*What happens...if the sun could do it? How come the moon happens to…?*' in Table 2, previously. Here, he is attempting to internalise and transform the ideas that he has gained through experience and through talking with others. This is an example of how some children were beginning to direct their attention, to abstract, or to establish connections – necessary processes in the development of academic concepts (Vygotsky, 1999).

The study indicated, too, that several of the older children (7- and 8-year-olds) were struggling with scientific concepts they have been taught. While they were acting intentionally on the concepts, they were often working hard to see relationships and causalities among the various elements of the system (see arrows and lines in drawings in Figures 4 and 6, above), at the same time, attempting to make some sense of them – hence the frequent fluidity noticed in their thinking (see Table 1 and also Charlie, earlier). Many of them knew, for example, that the heavenly bodies moved and that there were relationships between the Earth, the moon and the sun, and day/night cycles, but were not able to describe the complex nature of this relationship. Likewise, a few were able to articulate some links between different features of the water cycle,

but again could not explain these adequately. This intentionality in thinking was less obvious in many of the young children.

According to Vygotsky (1987, 1998), it is not until higher mental functions are being formed that the development of academic concepts becomes possible. That is, scientific concepts begin alongside the development of higher order functions such as conscious awareness, intentional perception and higher order remembering. Direct instruction in concepts prior to this is unsuccessful, and as he stated,

> [t]he teacher who attempts to use this approach achieves nothing but a mindless learning of words, an empty verbalism that simulates or imitates the presence of concepts in the child. Under these conditions, the child learns not the concept but the word, and this word is taken over by the child through memory rather than thought. Such knowledge turns out to be inadequate in any meaningful application…It substitutes the learning of dead and empty verbal schemes for the mastery of living knowledge (Vygotsky, 1987, p.170).

Therefore, a Vygotskian analysis looks not merely at the concepts children hold, but searches also for evidence of movement towards higher mental functioning – for planning, problem solving, focused attention, evidence of mediated remembering, and instances of self-directed thinking. As scientific concepts develop alongside higher mental functions, noting the presence or absence of these functions presents a more complex picture of children's thinking.

Conclusion

Adopting a sociocultural framework in research into young children's ideas about the world, especially when aspects of Vygotskian theorising are applied, offers the potential for gaining new insights into their thinking. Rather than being *alternative*, *naïve*, *intuitive* or *untutored* or 'lacking', a Vygotskian perspective can demonstrate that their thinking is rich and complex. It evolves and meanders around topics; it is often reflective and deliberate. Further, as opposed to being solely determined by particular mental schemes or mental models, thinking is mediated and is constituted with the thinking of significant others, especially family members.

Implications for science education research include consideration of the provision of appropriate cultural tools for children to use during the research activity. Further, paying attention to the mediated nature of thinking can be informative – that is, how people, speech (especially egocentric speech) and other signs and tools assist children in establishing meaning, and move towards the development of higher mental functioning. The provision of time and a relaxed, naturalistic atmosphere in research activ-

ities is also important – one which permits children to meander around topics and engage in egocentric speech.

Likewise, the teaching of science with young children is most effective when time is unhurried. Acknowledgement that they may hold multiple views at one particular point in time is important. However, they can be helped to reflect on these often-conflicting ideas. Drawing, as well as freedom to engage in egocentric speech, may be useful in helping them to do this. Recognition that scientific concepts begin *alongside* the development of higher mental functions is crucial, so assisting children to develop consciousness, reflection, organisation skills, problem solving, decision making and planning is important. Finally, teaching scientific concepts within a *system* of knowledge, helping children make links between those concepts – and with the everyday understandings they hold – leads to true, mature conceptual development.

It is contended that socioculturally informed conceptual tools, especially aspects of Vygotskian theorising, afford the possibility of making a significant contribution to research into young children's thinking about the world. Importantly, they offer the potential for gaining new insights into the positive, complex and powerful nature of that thinking.

Acknowledgements

I wish to thank sincerely the children in this study, and their teachers and families, for participating with me in this research. To you goes my utmost respect and appreciation. Pseudonyms have been used for all participants.

References

Anning, A., Cullen, J. & Fleer, M. (2004). Research contexts across cultures. In A. Anning, J. Cullen & M. Fleer (eds) *Early childhood education: Society and culture* (London: Sage), 1-15.

Bakhurst, D. (2007). Vygotsky's demons. In H. Daniels, M. Cole & J. Wertsch (eds) *The Cambridge companion to Vygotsky* (Cambridge: Cambridge University Press), 50-76.

Bodrova, E. & Leong, D. J. (2003). Learning and development of preschool children from the Vygotskian perspective. In A. Kozulin, B. Gindis, V. S. Ageyev & S. M. Miller (eds) *Vygotsky's educational theory in cultural context* (Cambridge: Cambridge University Press), 156-176.

Carey, S. (1985). *Conceptual change in childhood* (Cambridge MA: MIT Press).

Daniels, H., Cole, M. & Wertsch, J. (eds) (2007). Editors' introduction. In H. Daniels, M. Cole & J. Wertsch (eds) *The Cambridge companion to Vygotsky* (Cambridge: Cambridge University Press), 1-17.

Dove, J. (1998). Alternative conceptions about the weather. *School Science Review*, 79, 65-69.

Driver, R. (1981). Pupils' alternative frameworks in science. *European Journal of Science Education*, 3(1), 93-101.

Duit, R. & Treagust, D. F (2003). Conceptual change: A powerful framework for improving science teaching and learning. *International Journal of Science Education*, 25(6), 671-688.

Fleer, M. (1999). Children's alternative views: Alternative to what? *International Journal of Science Education*, 21(2), 119-135.

Fleer, M. (2009). Understanding the dialectical relations between everyday concepts and scientific concepts within play-based programs. *Research in Science Education*, 39(2), 281-306.

Fleer, M., Ridgway, A. & Gunstone, D. (2006). The cultural-historical construction of science learning within play based contexts. Paper presented at the *Thirty-seventh Annual Conference of the Australasian Science Education Research Association*. Canberra, Australie.

Fleer, M. & Robbins, J. (2003). 'Hit and run' research with 'hit and miss' results in early childhood science. *Research in Science Education*, 33(4), 405-431.

Giest, H. & Lompscher, J. (2003). Formation of learning activity and theoretical thinking in science teaching. In A. Kozulin, B. Gindis, V. S. Ageyev & S. Miller (eds) *Vygotsky's educational theory in cultural context* (Cambridge: Cambridge University Press), 267-288.

Göncü, A., Tuermer, U., Jain, J. & Johnson, D. (1999). Children's play as cultural activity. In A. Göncü (ed.) *Children's engagement in the world: Sociocultural perspectives* (Cambridge UK: Cambridge University Press), 148-170.

Haenen, J., Schrijnemakers, H. & Stufkens, J. (2003). Sociocultural theory and the practice of teaching historical concepts. In A. Kozulin, B. Gindis, V. S. Ageyev & S. Miller (eds) *Vygotsky's educational theory in cultural context* (Cambridge: Cambridge University Press), 246-266.

Henriques, L. (2002). Children's ideas about weather: A review of the literature. *School Science and Mathematics*, 102(5), 202-215

Leach, J. & Scott, P. (2003). Individual and sociocultural views of learning in science education. *Science and Education*, 12, 91-113.

Lemke, J. L. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching*, 38(3), 296-316.

Lemke, J. L. (2004). The literacies of science. In E. W. Saul (ed.) *Crossing borders in literacy and science instruction: perspectives on theory and practice* (Arlington VA: International Reading Association/National Science Teachers Association Press), 33-47.

O'Loughlin, M. (1992). Rethinking Science Education: Beyond Piagetian constructivism toward a sociocultural model of teaching and learning. *Journal of Research in Science Teaching*, 2 (8), 791-820.

Opfer J. E. & Siegler, R. S. (2004). Revisiting preschoolers' living things concept: A microgenetic analysis of conceptual change in basic biology. *Cognitive Psychology*, 49(4), 301-332.

Panofsky, C. P., John-Steiner, V. & Blackwell, P. J. (1990). The development of scientific concepts and discourse. In L. C. Moll (ed.) *Vygotsky and Education: Instructional implications of sociohistorical psychology* (New York: Cambridge University Press), 251-267.

Pfundt, H. & Duit, R. (1994). *Bibliography: Students' alternative frameworks and science education* (Kiel: IPN).

Piaget, J. (1972). *The child's conception of physical causality* (Totowa NJ: Littlefield, Adams & Co).

Piaget, J. (1973). *The child's conception of the world* (St. Albans, Herts: Paladin).

Robbins, J. (2005). 'Brown Paper Packages?' A sociocultural perspective on young children's ideas in science. *Research in Science Education*, 35, 151-172.

Robbins, J. (2006). *A sociocultural perspective on young children's thinking: An analysis of conversation, collaboration, contexts and cultural tools.* Paper presented at the thirty-seventh annual conference of the Australasian Science Education Research Association, Canberra, Australie.

Rogoff, B. (1998). Cognition as a collaborative process. In W. Damon, (chief editor) and D. Kuhn & R. S. Siegler (Volume eds) *Cognition, perceptions and language*. *Handbook of Child Psychology* (NY: John Wiley & Sons, Inc), 679-744.

Rogoff, B, (2003). *The cultural nature of human development* (Oxford: Oxford University Press).

Roth, W.-M. (2000). From gesture to scientific language. *Journal of Pragmatics*, 32, 1683-1714.

Roth, W.-M. (2004). Gestures: The leading edge in literacy development. In E. W. Saul (ed.)

Crossing borders in literacy and science instruction: perspectives on theory and practice (Arlington VA: International Reading Association/National Science Teachers Association Press), 48-67.

Roth, W.-M. & Lawless, D. (2002). Scientific investigations, metaphorical gestures, and the emergence of abstract concepts. *Learning and Instruction*, 12, 285-304.

Roth, W.-M. & Welzel, M. (2001). From activity to gestures and scientific language. *Journal of Research in Science Teaching*, 38, 103-136.

Samarapungavan, A., Vosniadou, S. & Brewer, W. F. (1996). Mental models of the earth, sun, and moon: Indian children's cosmologies. *Cognitive Development*, 11, 491-521.

Siegal, M., Butterworth, G. & Newcombe, P. A. (2004). Culture and children's cosmology. *Developmental Science*, 7(3), 308-324.

Schoultz, J., Säljö, R. & Wyndhamn, J. (2001). Heavenly talk: Discourse, artifacts, and children's understanding of elementary astronomy. *Human Development*, 44(2/3), 103-118.

Traianou, A. (2006). Teachers' adequacy of subject knowledge in primary science: Assessing constructivist approaches from a sociocultural perspective. *International Journal of Science Education*, 28(8), 827-842.

Tytler, R. (2002). Teaching for understanding in science: Constructivist/conceptual change teaching approaches. *Australian Science Teachers' Journal*, 48(4), 30-35.

Tytler, R., Prain, V. & Peterson, S. (2007). Representational issues in students learning about evaporation. *Research in Science Education*, 37, 313-331.

Vosniadou, S. & Brewer, W. F. (1992). Mental models of the earth: A study of conceptual change in childhood. *Cognitive Psychology*, 24, 535-585.

Vosniadou, S. & Brewer, W. F. (1994). Mental models of the day/night cycle. *Cognitive Science*, 18, 123-183.

Vosniadou, S., Skopeliti, I. & Ikospentaki, K. (2004). Modes of knowing and ways of reasoning in elementary astronomy. *Cognitive Development*, 19, 203-222.

Vygodskaya, G. L. (1995). His life. *School Psychology International*, 16(2), 105-116.

Vygotsky, L. S. (1987). *The collected works of L. S. Vygotsky, Vol. 1: Problems of general psychology* (R. W. Rieber & A. S. Carton, eds, New York: Plenum Press).

Vygotsky, L. S. (1997). *The collected works of L. S. Vygotsky, Vol. 4: The history of the development of higher mental functions: Cognition and language* (R. W. Reiber, ed., New York: Plenum Press).

Vygotsky, L. S. (1998). *The collected works of L. S. Vygotsky, Vol. 5: Child Psychology* (R. W. Reiber, ed., New York: Kluwer Academic/Plenum Publishers).

Vygotsky, L. S. (1999). *The collected works of L. S. Vygotsky, Vol. 6: Scientific Legacy* (R. W. Reiber, ed., New York: Plenum Press).

Watson, L. (1997). Children's misconceptions and conceptual change. *Australian Journal of Early Childhood*, 22(2), 12-16.

Wertsch, J. (2007). Mediation. In H. Daniels, M. Cole & J. Wertsch (eds) *The Cambridge companion to Vygotsky* (Cambridge: Cambridge University Press), 178-191.

Woodhead, M. (2000). Towards a global paradigm for research into early childhood. In H. Penn (ed.) *Early childhood services: Theory, policy and practice* (Buckingham: Open University Press), 15-35.