Chapter 14
Vygotsky and Primary Science

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This chapter examines some of Vygotsky's ideas in relation to children's development and early learning in science. The literature concerning children's learning in science at primary (elementary) school is surprisingly neglectful of the work of Vygotsky, with most emphasis still being placed on Piagetian ideas (Anne Howe 1996). Three main Vygotskian ideas are explored in this chapter in relation to young children's learning of science: the zone of proximal development, cultural mediation and the importance of play for the development of abstract thought. The chapter contextualises Vygotsky's ideas specifically in relation to improving both children's experience of primary science and their development of scientific concepts.

Science education has historically moved between three broad theoretical frameworks that have governed policy and practice in school science: behaviourism, cognitive constructivism and sociocultural theory. Behaviourism is based on the principle that scientific learning is a behavioural change that can be induced via appropriate stimuli; it follows the work of Ivan Pavlov (1849–1936), Edward Lee Thorndike (1874–1949) and Burrhus Skinner (1904–1990). In cognitive constructivism, it is supposed that children discover scientific concepts as a consequence of applying logical thought to results of interaction with objects and phenomena; it is based mostly on the work of Jean Piaget (1896–1980). Sociocultural theory applied to science learning would suggest that learning science is bound by the specific social and cultural context available to the learner. It presupposes that learning occurs first between people and then in the individual. It argues that scientific concepts are *not* formed by repeated experiences, but by combining experiences with intellectual operations guided by language; much of this work is based on the writing of Lev Semenovich Vygotsky (1896–1934).

Both Vygotsky and Piaget maintained that children are not just small adults and that children's minds work in a different way from those of adults, using different

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means. However, whilst Piaget argued that children need to reach a certain stage of development before they can learn more complex abstractions, Vygotsky contended that learning actually leads development and that the teacher should always be challenging the children. Piaget maintained that we need to discover innate, internal laws that govern the child's mind, whereas Vygotsky highlighted the importance that culture plays in determining a child's development. Essentially, Piaget was more interested in the 'average' child, whereas Vygotsky focused on the importance of the unique social and cultural conditions that govern the learning environment of each child. Vygotsky made the case that each child is born into a particular cultural society and that his or her development is mainly directed by the internalisation of cultural signs and symbols which he or she later uses as psychological tools (e.g. memory, thinking, speech, etc.) to mediate learning (Elena Yudina 2007). Yudina gives the example of a child learning to eat with a spoon, which is mediated by an adult (usually the mother). The way in which the child uses the spoon depends on those cultural norms expressed by the mother. The spoon could be considered as an external tool to aid eating; language and gestures become internal tools to aid learning.

In terms of primary school science, Piaget's work led to the idea that children cannot be taught certain concepts until they have reached a certain developmental level and also that skills-based science learning and 'hands-on' approaches provide the most effective learning environments for classroom science. Vygotsky, on the other hand, maintained that child development is *not* a linear process and that there are different levels of development for different functions: at the one time, some cognitive functions can have 'matured', whilst others are in the process of maturing. So, children will *not* develop concepts using skills-based and hands-on approaches unless these are contextualised within an appropriate conceptual framework. Only then can the child abstract meaning from the experience. New, similar experiences can then be integrated into the conceptual framework, which becomes more familiar and concrete with each subsequent related experience.

Zone of Proximal Development

There is currently much discussion and debate about what Vygotsky actually meant by the 'zone of proximal development' (ZPD). My experience of the term was that it was the only reference to the work of Vygotsky in many education textbooks, and was never adequately explained. The simplistic definition of the ZPD found in many textbooks and other publications involves the 'gap' between what a child can achieve unaided and with help; for example, Louis Cohen et al.'s (2004) in *Guide to Teaching Practice*. This definition could be said to imply little more than that teachers need to help children! Anton Yasnitsky (2008) cites Annemarie Palincsar (1998), who argues that the ZPD is probably one of the most used and least understood educational concepts, and Mercer and Fisher (1992), who point out the danger in the term ZPD being used as a fashionable alternative to Piagetian terminology. Yasnitsky (2008) also cites Jonathan Tudge's (1999) observation that, in the six volumes of

Vygotsky's collected works, the ZPD only appears on a few pages in the thousands that he wrote. Bert van Oers (2007), however, discusses the complexity of the ZPD and shows how the concept was an evolving notion even during the short research life of Vygotsky; he used it initially as an index for intellectual potential and later as an educational concept focusing on the conditions needed to establish a ZPD.

Margaret Gredler and Carolyn Claytor Sheilds (2008) describe Vygotsky's argument that two children of the same age and the same 'actual' level of cognitive development not being able to solve a new problem with the same amount of help. Despite being measured at the same level, one child might solve the task with very little help, whilst the other might not solve it even after several different interventions designed to support the learning. Such interventions could involve: demonstrating the problem solution and seeing if the child can begin to solve it; beginning to solve it and asking the child to complete it; asking the child to solve the problem with the help of another child who is considered to be more able; and explaining the principle of the needed solution, asking leading questions, analysing the problem with the child, etc. Vygotsky considered performance on summative tests as an indication of the child's past knowledge and argued that 'instruction must be orientated towards the future, not the past' (Vygotsky 1962, p. 104). He defined the ZPD as: 'those functions which have not yet matured but are in the process of maturing… "buds" or "flowers" of development rather than "fruits" of development. The actual development level characterises the cognitive development retrospectively while the ZPD characterises it prospectively' (Vygotsky 1978, p. 86). He suggested that teaching/learning in the ZPD creates new levels of cognitive development that would not have been reached otherwise and that formal instruction is necessary to lift the child to the level of systematic scientific thinking. Useful instruction 'impels or awakens a whole series of functions that are in a stage of maturation lying in the zone of proximal development' (Vygotsky 1987, p. 212).

Bert van Oers (2007, p. 15) points out that the ZPD 'is *not* (emphasis added) a specific quality of the child, nor is it a specific quality of the educational setting or educators… it is… collaboratively produced in the interaction between the child and more knowledgeable others'. Gordon Wells (1999) and Tudge and Scrimsher (2003), together with many other researchers, also discuss the ZPD as an interaction between the students and co-participants. The interaction definition, whilst popular, is contested. Seth Chaiklin (2003) argues that the maturing functions described above by Vygotsky (1978) are not created in an interaction, but that interaction helps in identifying the existence of such functions and the extent to which they have developed.

Vygotsky contended that a full understanding of the ZPD should result in a re-evaluation of the role of 'imitation' in learning. His notion of 'imitation' is not meant as copying – more as emulation of an activity as part of the learning process. For example, a child learning to add, knit or dance emulates the teacher before doing the task by himself or herself. This type of activity coincides with the ZPD in the sense that it bridges what the child can do with help and then alone.

Vygotsky's description of the ZPD was that of maturing psychological functions that are required for the understanding of more abstract, scientific concepts. The conditions required to 'create' a ZPD to promote maturation of these functions is

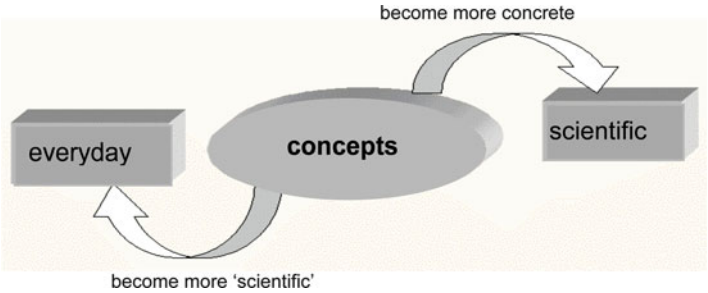

Fig. 14.1 Science concept formation as a dialectical process

of prime importance to children's early development of scientific concepts. Vygotsky maintained that scientific concept development is dialectical, as opposed to a linear process, in which spontaneous, or everyday, concepts become more abstract or scientific as a child learns. The scientific concepts, in becoming more familiar, become more concrete (see Fig. 14.1).

A zone of proximal development (ZPD), which can aid in the formation of scientific concepts, can be set up by involving children in shared activities in which they are afforded *meaningful* participation. Vytaly Rubtsov (2007) describes such a setting involving 7- to 9-year-old children:

> Two children must work together to balance a set of weights on a calibrated arm by moving, adding or removing weights. To solve this problem, they must take into account the relationship between each weight and its distance from the arm's centre of gravity. One participant is allowed to move the weights along the arm but not to add or remove weights; the other may increase or reduce the number of weights, but not move them. This division of activities, therefore, requires the two participants to work together, coordinating their activities in order to solve the task successfully. As the children move to the next problem, they switch roles. (p. 12).

Rubtsov (2007) cautions that such activities, whilst promoting reflective thinking, do *not* guarantee that each child will be able to identify the essential elements of the task. He suggests that, to increase the effectiveness of the activity, children should also use *pictorial and symbolic models* to represent the problems that they are solving and the steps that they use to solve them. Hence, they will be applying a conceptual framework into which their activity can be contextualised and made scientifically meaningful. This, I believe, is the crux of improving primary science by using a Vygotskian perspective. The pictorial and symbolic models, together with the discussion, become more meaningful to the children (and more so again with continued use with new, similar activities). Such work promotes thinking and stimulates pupils to reflect and explain in order to understand how their experiences and context-bound knowledge fit into a larger system (Howe 1996). The teacher is essential here to guide the work and provide the conceptual framework. Howe (1996) argues that, in contrast, a Piagetian approach involves children working on their activity without teacher intervention. She maintains that 'decontextualized tasks, chosen to represent a process but unrelated to children's everyday knowledge or interests, would not have a place in a science curriculum informed by a Vygotskian perspective' (p. 46).

Most science educators contrast this approach with the conceptual change model, popularised by George Posner et al. (1982) and Roger Osborne and Peter Freyberg (1985). This assumes that children come to school with misconceptions, or alternative frameworks, about natural phenomena that need to be elicited and then challenged (typically via demonstration or experimentation) to induce cognitive conflict and eventual reconciliation and acceptance of the logical, scientific concept. The conceptual change approach has been found wanting in several respects, including the observation that many 'misconceptions' persist, even after teaching involving cognitive conflict and initial acceptance of the scientific explanation has taken place (e.g. Shulman 1986). Perhaps a reason for such persistence of 'misconceptions' is the lack of relevant context for the pupils when the learning takes place. Howe (1996) argues that, using a Vygotskian perspective, children's ideas would be elicited, *not* to be challenged, and used to 'establish a foundation on which to build new knowledge or as a point of entry into the system of relationships that are eventually to be understood' (p. 48). Such understanding requires *time* so that children can move back and forth between everyday and scientific concepts, making sense of and discussing experiences in relation to the conceptual framework. The emphasis here is *not* on the solitary learner, but on interacting, negotiating and sharing to help integrate everyday concepts into the system of relational concepts. Howe (1996) raises some very important research questions based on a Vygotskian approach to science learning: 'What problem solving strategies do children use in everyday life that have been ignored in school and can be used as a basis for science teaching? What are the differences between the everyday science concepts of children from different socioeconomic, ethnic and regional backgrounds and how does this affect what is learned?' (p. 48).

Play

There is a vast amount of literature about play in primary science, with much of it debating whether the focus should be on teaching academic skills or engaging young children in make-believe play as a developmental activity (Elena Bodrova and Deborah Leong 2007). Recently, much of the focus tends to be more in the direction of the former. Bodrova and Leong (2007) suggest that there is a false dichotomy between play and academic skills when considered from a Vygotskian perspective. Indeed, Vygotsky maintained that creating an imaginary situation in play is a means by which a child can develop abstract thought. He considered play as a precursor to academic learning in two ways (Fig. 14.2).

The best kind of play to develop abstract thought involves children in using unstructured and multifunctional props, as opposed to those that are realistic. The former type of props strongly promotes language development to describe their use (e.g. a cardboard box can serve first as a shop, then as a school, then as home). Vygotsky said that this repeated naming and renaming in play helps children to master the symbolic nature of words, which leads to the realisation of the relationship

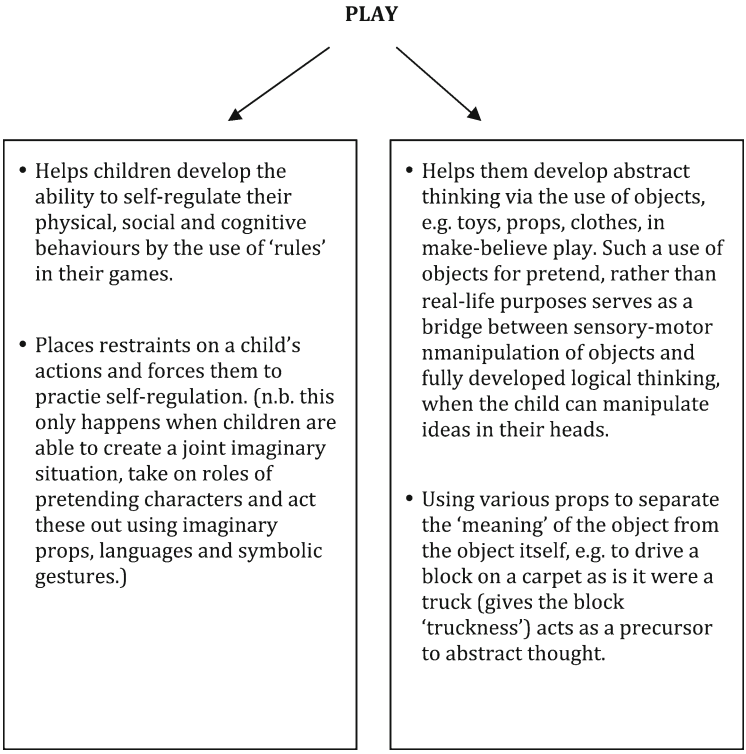

Fig. 14.2 Ways in which imaginative play is a precursor to academic learning

between words and objects and then of knowledge and the way in which knowledge operates.

This type of play is not often seen in the classroom in school – many 3- to 5-year-old children are playing like toddlers, just manipulating objects and not engaging significantly with other children.

Vygotsky's perspective on play connects it to the social context in which a child is brought up. He suggested that adults and older children should also be involved to enable younger children to model both roles and the use of props. Vygotsky promoted the notion that play, as learning, should lead development, as opposed to the more accepted one of development leading learning or play. Nikolai Veresov (2004) discusses learning that takes place in or within children's play. He uses the Vygotskian example of a child playing with a stick by using it as a horse. The child learns about the object (stick) and its objective physical properties, but also decides whether such properties allow or prevent the stick from becoming a horse. If the object does not suit the play task, the child stops playing with it. Veresov, in the same article, proposes that learning in play is a movement from the field of sense to the field of meaning; 'sense finds a suitable object, that is, sense objectifies itself' (p. 13). He exemplifies the sense-meaning dimension using a teacher-child two-part vignette in which the teacher first asks the child to suppose that he has two apples,

and then gives one to someone and asks the child how many apples he now has. 'Two' replies the child and, on further questioning, he tells the teacher that he has two because he never gives his apples to anyone else. In the second part, the teacher asks the same child to suppose that someone else has two apples and gives one to him – she asks how many apples the other person now has. The child replies 'one' and explains that he or she would have one each. Veresov (2004) argues that the task is the same (a calculation of 2–1=1), but that the sense of the task must be in the child's zone of proximal development.

Vygotsky theorists point towards empowering children through play. For example when modelling a situation in play involving, say, an imaginary parent or teacher or grocer or doctor, the child becomes, in Vygotsky's terms, 'a head taller'. Vygotsky (1978, p. 102) himself suggested that play creates a ZPD of the child:

> This strict subordination to rules [during play] is quite impossible in life, but in play it becomes possible: thus, play creates a zone of proximal development… In play a child always behaves beyond his average age, above his daily behavior; in play it is as though he were a head taller than himself.

In primary science, a Vygotskian perspective would presuppose that teachers promote role-plays and imaginary play in science learning for children throughout the primary school in order to further the development of abstract, conceptual thought. There would be a lot less focus on individual play with objects and more on collective play, preferably involving older children who can model both roles and the use of props for the younger ones.

Cultural Mediation

Whilst it is a common observation that children learn from adults and other children, it is less obvious how this happens. Vygotsky suggested that the child appropriates cultural tools and ways to use them; the child interacts with the environment via the mediation of cultural agents. The child is the subject, not the object of learning (Yudina 2007). Piaget, on the other hand, argued that the child's learning represented biological adaptation to the environment, a far more passive role.

The main cultural tool, according to Vygotsky, is language, which can be thought of as a sign system. For learning to take place, language first needs to be internalised by the child (see Fig. 14.3). Vygotsky noted the importance of cultural mediation of these sign systems in humans, which does not occur in animals. For instance, in the everyday activity of eating, animals of a particular species all eat in the same way whereas, in humans, the way in which a person eats strongly reflects the culture in which they were raised and there are many, many different ways in which humans consume their food. Vygotsky argues that cultural mediation is just as important in the consideration of how, and indeed what, children learn.

In terms of learning, it must be remembered that the 'mediator', such as language, carries *meaning and sense*, as well as functioning as a tool, and therefore must be *interpreted* by the child (Vladimir Zinchenko 2007). Therefore, the child contributes

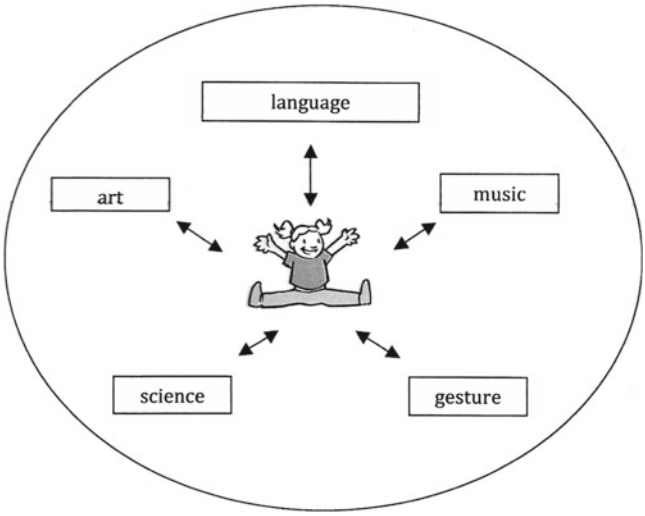

Fig. 14.3 Examples of sign systems used by a child to interact with the external world

to the culture, and continues this contribution in many ways throughout his or her life. Children's learning by way of cultural mediation can be summed up as follows:

$$\text{child} \xrightarrow[\text{mediated by cultural agent}]{\text{interacts with environment}} \text{higher psychological functions}$$

Yuriy Karpov and Carl Haywood (1998) argued that Vygotsky maintained that education entails two fundamental forms of mediation: mediation via cultural concepts and mediation via social interaction, which can be considered separately, but are in reality inseparable. It is through such mediation, according to Vygotsky, that 'we can take stock not only of today's completed processes of development, not only of cycles that are already concluded and done, not only of processes of maturation that are completed; we can also take stock of processes that are now in the state of coming into being, that are ripening, or only developing' (Wertsch (1985), pp. 447–448; cited in Wertsch 1985, p. 68). In order to aim the mediation at those abilities that are in the process of ripening, teachers must be assessing the children's learning before and during, as well as after, each learning sequence. The current emphasis on different modes of formative assessment, or assessment for learning (AfL) (see Black and Wiliams 1998), provides a basis upon which this can be achieved.

The role of the children in learning and development is much more active and agentic in a Vygotskian interpretation of how learning occurs through interaction with their environment, than if we use the Piagetian model based on their adaptation to the environment. Piaget's model leaves little room for the child to alter the environment as a consequence of his or her learning. In primary science learning, the Vygotskian interpretation allows for the sharing of ideas about phenomena between children and their peers and teachers, which is essential for the exposure of

different levels of understanding to be addressed. Vygotsky contended that higher cognitive functions originate from the interaction between people, but we need to *teach* decontextualised contexts to enable the facilitation of cognitive growth. Teaching decontextualised concepts with the experience enables the students to create and enliven a cognitive framework in which they can contextualise and abstract their experiences! The fact that a person boils water in a kettle and observes steam coming out for years, does not necessarily (and only very rarely) lead to them discovering the concept of evaporation. Only when they are taught about evaporation and encouraged to link this learning with the kettle experience can most people make sense of the decontextualised concept of evaporation, and to situate other experiences, such as the drying up of puddles, within the initial framework of evaporation and then in the broader conceptual framework of the water cycle.

Conclusion

According to Vygotsky, learning *leads* development; so do not wait until children are 'old' enough to learn! Leif Strandberg (2007) contends that, as teachers, we need to promote activities that: develop interactions between children and between adults and children; give children access to tools and words; change around the learning environment to suit different activities and involve children as creative coworkers (see Fig. 14.4).

Such methods liberate adults and children from a retrospective, diagnostic and resigned pedagogy and enable a more forward-looking perspective on learning comprising performing as opposed to explaining. They also provide, according to Strandberg (2007), a sense of hopefulness for what comes next.

In primary science activities, teachers might consider expanding their use of curricular activities that include:

- Think, pair share
- Peer learning
- Mediational artefacts
- Science term of the day (or week)
- Adaptation of the learning environment
- Use of role-play and stories to promote Vygotsky-type imaginary play
- Extending 'play' activities to older children to aid abstract concept formation.

In summary, a Vygotskian approach to primary science highlights the importance of ensuring that practical activities are contextualised within a conceptual framework, children are encouraged to discuss their developing understanding with peers and teachers, and time is allowed for contextualised experiences that foster the development of such concepts. Role-play and collaborative, imaginative play with children of different age groups would be encouraged throughout the primary school to facilitate the development of abstract thought. Teachers mediate pupils' learning by addressing social and cultural influences in their provision of appropriate educational tools and

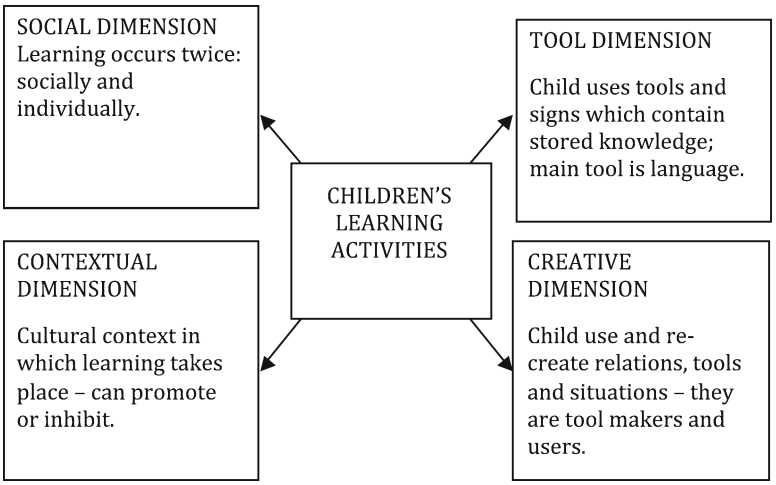

Fig. 14.4 Strandberg's four dimensions to children's activities

they monitor children's progress as they attempt to identify and teach within their zones of proximal development. Teachers use formal instruction alongside hands-on practical activities that are relevant to their experience and interests to enable children constantly to switch between everyday and scientific concepts until they have been adjudged to have achieved an appropriate understanding. It could be argued that such a change in teaching/learning approach requires a level of theoretical synthesis between some of Piaget's ideas, which dominate much of the current enactment of science teaching, with the more operational aspects of Vygotskian theory. In this regard, we can learn a lot from the literature on incorporating Vygotskian approaches to teaching in early years and in second language learning.

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