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Abstract: A Vygotskian perspective can provide insights that will be useful as we seek to make teaching more effective and meaningful to both students and teachers. Vygotsky emphasized the role of culture and of social interaction in education and advocated teaching that encourages and guides learners but never forces or dictates. He believed that children learn through active participation in a collaborative effort with teachers, parents or older children. Current suggestions for teaching for conceptual change emphasize the need for students to recognize and bring to consciousness their misconsceptions as a prelude to conceptual change with the assumption that, as the internal idea is externalized and viewed objectively, contradictions will be recognized and reconciled. From a Vygotskian perspective the process is reversed as ideas gathered from the culture through social interaction are internalized. This paper presents some of Vygotsky's contributions to thought in this field and considers the implications for educational strategies in science teaching.

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A Vygotskian Perspective on Teaching for Conceptual Change

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The problem of effecting conceptual change is confronted daily by elementary and middle school teachers whether they are trying to convince primary children that the world has the shape of a ball or explaining to seventh graders why they should believe that solid objects are made up mostly of empty space. In both cases children come to school with definite ideas of their own, the scientific concepts are counterintuitive and there are no available first hand experiences that are likely to stimulate conceptual change. Models of conceptual change that have been most influential in science education assume that each child comes to school with misconceptions about natural phenomena, that these misconceptions need to be elicited, challenged by explaining or demonstrating contrary examples and corrected by providing a more general concept that the child will accept and assimilate. The aim is to guide students toward accepting current scientific views and incorporating them in their cognitive schema.

This problem was addressed more than sixty years ago by the Russian psychologist Lev Vygotsky who studied children's concept formation and conceptual change as part of his extensive work on the interrelationship of thought and language. One purpose of his work was to establish both an experimental and a theoretical basis for instruction. '"To devise successful methods of instructing the schoolchild in systematic knowledge," he wrote "it is necessary to understand the development of scientific concepts in the child's mind" (Vygotsky, 1986, p. 146). He also expected that his results would have theoretical significance for psychology. The results of his empirical work and the explanations and hypotheses that grew out of it may provide new insights into the issues we are considering in this symposium.

If you ask why we are now getting insights from work that was produced nearly sixty years ago, the answer is found within the history of the Soviet Union. Vygotsky was born in western Russia in 1986. At the time of the Russian Revolution he was completing his university studies in law and humanities in Moscow and was soon to begin a teaching career at the secondary level. He developed an interest in psychology, and through his own experiments and wide reading he entered upon a career in psychology in 1924, becoming the center of a group of brilliant young psychologists and other intellectuals who were stimulated and energized by the events of the time and by the personality and ideas of Vygotsky himself. At the time of his death at the age of 37 Vygotsky had produced a body of important work which was suppressed for years in the Soviet Union and was almost unknown in the West until the 1960's.

Some of Vygotsky's central ideas about concept formation, conceptual change and the relation of school instruction to cognitive development are presented and discussed in this paper. Most of the ideas are taken from the fifth and sixth chapters of his book Thought and Language , which was first published in this country in 1962 , has since been retranslated and published in a new edition and has also been published with a different translation and a more complete text as Thinking and Speech (Rieber & Carton, 39-285). Much of this book is a response to Piaget's work up to that time, with particular attention to The Language and Thought of the Child (Piaget, 1923), and his other work focusing on the formation of concepts during childhood and early adolescence. These chapters were written near the end of Vygotsky's life; the book was published posthumously. We can assume that many of the ideas would have undergone further development and elaboration if he had lived longer but the book's sixth chapter, titled "The Development of Scientific Concepts in Childhood" and frequently cited here, has been called the place where "the larger scope of Vygotsky's philosophical, psychological and practical views are revealed"(Rieber & Carton, p. 365).

The aspects of Vygotsky's work that have received most attention among educators and psychologists are his arguments for the cultural basis of cognition and for the existence of a "zone of proximal development" (see, for example, Adams, 1972; Moll, 1990; Wertsch , 198 5). The latter refers to the idea that there is a zone for each child which is bounded on one side by the developmental threshold necessary for learning and on the other side by the upper limit of the child's current ability to learn the material under consideration. His work on concept formation has received little attention although it addresses questions and issues of continuing concern to science educators and others.

SPONTANEOUS AND NONSPONTANEOUS CONCEPTS

Vygotsky distinguished between (a) spontaneous or everyday concepts formed from a child's experience and independent thinking and (b) nonspontaneous or scientific concepts taught in school. He used the term "scientific concepts" in a broad sense, encompassing concepts in the social sciences, language and mathematics as well as the natural sciences. He associated scientific concepts with systematic, hierarchical knowledge as opposed to the non-systematic, unorganized knowledge gained from everyday experience.

Piaget had earlier made the distinction between the two kinds of concepts but, according to Vygotsky, had failed to see the interaction between the two. Vygotsky believed that there is an important connection and interaction between the two; what a child is learning

in school influences the course of development of concepts acquired through everyday experience and vice versa. The crucial difference between the two categories of concepts is the presence or absence of a system. Spontaneous concepts are based on particular instances and are not part of a coherent system of thought; on the other hand, scientific concepts (i.e. those learned in school) are presented and learned as part of a system of relationships . When a pupil has reached some understanding of the organization of concepts into a hierarchical system of interrelationships then this knowledge influences understanding of related everyday concepts by transforming and giving new direction to them. This takes place as the child reflects on what he or she has learned in school and, by reflection, raises to the level of consciousness what had previously been nonconscious; in contemporary terms the child is using metacognitive processes.

Vygotsky compared the formation of the two kinds of concepts by using the analogy of learning a foreign language as opposed to learning the mother tongue. A child learns to speak the native language without thinking about tenses, sentence structure, pronunciation or inflection, but all of these become matters of great concern when learning to speak a foreign language. Learning to speak a language from the rules of grammar would be similar to learning to walk by using the laws of equilibrium but once some mastery of the system has been attained in the nonnative language the learner then understands his native language from a new perspective. The native language is seen as but one instance among many; the grammar and sounds are eventually understood to be part of a larger system that includes innumerable human languages.

INTERRELATIONSHIP OF CONCEPTS

Vygotsky sought to show that spontaneous concepts grow and change under the influence of instruction in scientific concepts and that scientific concepts develop fully as they incorporate related everyday concepts. Scientific (nonspontaneous) concepts are taught in school by means of verbal definitions and explanations or mathematical symbols and reside on a level of abstraction; pupils learns to define or explain a given concept on a verbal level but in order to be fully grasped a concept has to be applied to specific examples. In applying abstract concepts to specific examples student thinking descends to the concrete, moving from the plane of abstract thought to the phenomenon represented by the words or symbols. In contrast, everyday concepts develop outside a definite system; in order to be understood in relation to what has been learned in school, thinking must move upward toward abstraction and generalization. The child eventually comes to see his spontaneous concepts as part of a system of relationships and, at the same time, and comes to see how the phenomenon he has experienced fits into the scientific system he has been taught.

Other psychologists had claimed or assumed that scientific concepts do not have their own internal history but are adopted from the domain of adult thinking as given. Vygotsky argued, on the contrary, that a scientific as well as an everyday concept is not taken in all at once in completed form but develops over time; teaching scientific concepts in school is not the end but the beginning of the development of a concept. There is movement back and forth in the child's mind between the spontaneous and the nonspontaneous concepts until they come together in a system. The transition from the abstract to the concrete is as difficult for the pupil to negotiate as the transition from the concrete to the abstract. That is, a student may be able to define or give an explanation of a concept but still have great difficulty in applying it to the familiar observations of the everyday world. However, until this is accomplished there is a danger that the concept learned in school will remain a verbalism rather than a true concept.

Let me apply this idea to a simple example, the concept of *animal.* By the time children enter kindergarten most of them will have developed a concept of *animal* which includes only vertebrates and may include only mammals with the exception of humans. At some time during the first years of school the teacher will explain that the scientific term *animal* is much more inclusive , that it includes insects and human beings and that animals have been classified in certain ways. It is obvious that this idea will not be immediately assimilated and it is reasonable to believe that the child will be thinking about it from time to time over months or even years before the enlarged concept becomes more than a verbalism and the child's spontaneous concept is integrated with the scientific concept.

Or consider the development of concepts about the sun and the moon and day and night. A young child develops concepts about the moon and the sun and about day and night; that is, the child knows that the moon and sun exist and that day and night come and go with regularity. He or she may have developed some ideas about these phenomena and has probably heard by age 6 or 7 that there is some connection between the sun and the coming of day and night, but this knowledge is largely nonconscious and unsystematic. When the child learns in school about the solar system, the movements of the earth and moon, that our earth is one of many planets and the moon is one of many moons, that the sun is a star, etc., that knowledge is connected into a system, including definitions, from the beginning. In order to be assimilated and understood, the scientific concept must be applied to concrete examples; the child or adolescent must think about what this means in terms of his or her experience of these phenomena. At the same time, the child must fit his everyday concepts into the system learned in school. The child must go from the abstract to the concrete and from the concrete to the

abstract. Movement in both directions is necessary. That this does not always happen was illustrated dramatically when a survey of Harvard graduates showed that many of them could not give an explanation for the occurrence of seasons of the year.

INTERDEPENDENCE OF THOUGHT AND LANGUAGE

Central to Vygotsky's thinking was the importance of language in mediating thought. The belief in the primacy of language is a fundamental difference between his view of concept development and that of Piaget. Except for his work on egocentric speech, Piaget gave little attention to language and never assigned it a primary role in conceptual development. For Piaget language was a means of expressing thoughts that had already developed. For Vygotsky language was central to the development of thought; words were the means through which thought was formed and reified.

The semantic components of words change as a child's thinking develops and new meanings are attached to words already known. Children may use the same words that adults use in speaking of observations, phenomena or ideas but the words do not carry the same meaning for the child as they carry for the adult. Since words are dynamic rather than static, the relationship of thought to word constantly changes, undergoing a continual process from thought to word and word to thought. "The relation between thought and word is a living process; thought is born through words. A word devoid of thought is a dead thing and a thought unembodied in words remains a shadow" (Vygotsky, 1986. p. 255).

Vygotsky rejected associationism, a popular theory in his time, as an explanation for concept formation. A child may have a nonconscious understanding of concepts before being able to verbalize them but associations alone will not lead to concept formation; a concept cannot be fully developed into conscious form without language. If we apply this theory to teaching it becomes clear that it is important to go beyond direct experience in teaching scientific concepts and to mediate experience with words; experience alone is not enough since the experience is an isolated observation unless it is put into words and understood in a larger context. Concepts are formed, not by an interplay of associations but by an intellectual operation in which such mental functions as memory, attention and inference participate and in which language is the guide. Putting things into words is an essential part of science teaching and learning, a process that depends on interaction between teacher and learner because the vocabulary for science cannot be discovered independently by the learner. Putting it into words centers attention, clarifies thinking, provides a means of symbolizing thought and is an integral part of the

process of concept formation. The development of conscious awareness through the use of language propels thinking forward toward conceptual understanding.

THE RELATION OF SCHOOL INSTRUCTION AND DEVELOPMENT

Vygotsky rejected the view that learning must wait on development; that is, the notion that the key to instruction is the determination of the developmental levels that various mental functions must reach in order for instruction to be feasible. This is another area in which he disagreed with Piaget, who gauged the level of development by determining children's thinking on subjects about which they had been taught nothing. While it is common sense that a six-year old cannot be taught algebra, for example, and that a necessary minimum level of development exists, this does not mean that instruction is extraneous to mental development. A series of studies of the learning of basic school subjects led Vygotsky to the conclusion that "the development of the psychological foundations for instruction in basic subjects does not precede instruction but unfolds in a continuous interaction with the contributions of instruction" (Vygotsky, 1986. p 184). Vygotsky recognized that a spontaneous concept must have reached a certain level for the child to be able to absorb a related scientific concept; that is, there is a lower threshold for instruction but the upper threshold must be considered as well. Instruction should "march ahead" of development and lead it.

This line of reasoning led to the idea of the zone of proximal development (ZPD), a construct that, as mentioned above, has received much attention since Vygotsky's work has become more generally known. Van der Veer and Valsimer (1991) give the following definition:

> The zone of proximal development is the distance between his actual development , determined with the help of independently solved tasks, and the level of potential development of the child, determined with the help of tasks solved by the child under the guidance of adults and in cooperation with his more intelligent partners. (p. 337)

The basic notion is that intelligence is measured not by what a child already knows but by what he or she can learn under adult or peer guidance through collaboration and imitation. Imitation is not considered to be a mechanical activity since it can only be carried out when the learner possesses the necessary mental and physical means to perform the activity. This view of intelligence has suggested the idea of "scaffolding", another idea that has gained recent popularity. Scaffolds are the props or aids that an adult or more advanced peer uses in helping a pupil advance to a higher level of knowledge and understanding. The teacher, working with the pupil, explains, supplies information, questions, corrects and makes the pupil explain.

Through this process the pupil gradually moves from being able to solve a problem or explain a concept with assistance from a teacher or tutor to being able to do it on her own.

IMPLICATIONS FOR SCIENCE INSTRUCTION

The purpose of this paper is not to give prescriptions for instructional strategies but to present a perspective that may take our thinking in some new directions. If we take Vygotsky seriously we might start by rethinking the labeling of children's spontaneous concepts as "misconceptions" and our tendencies to refute them rather than trying to help children integrate them into more inclusive systematic frameworks. It is not, after all, a misconception that the earth is flat; within the child's experience the earth is flat.

The expectation that a scientific concept can be learned within the space of a few days, weeks or even months is another notion that needs reexamination. There is a danger that the current movement toward "performance objectives" will result in teachers' rushing students through a series of lessons on complex concepts without sufficient time for reflective thinking, integration with existing ideas or practice in moving from the abstract to the concrete and back again. Concept development cannot take place in these circumstances.

Traditional science laboratories, so much criticized of late, can also be seen in a different perspective; they can be seen as a means of applying abstract principles to concrete situations rather than as empty exercises proving concepts pupils have already learned. Many concepts are presented in upper elementary grades by means of graphs, diagrams and definitions; these remain abstract and unassimilated without opportunities to experience the phenomena in concrete situations.

Another obvious implication is the importance of language in concept development. Vygotsky's translators tell us that the word he used is actually "speech" rather than language with emphasis on the uses of "inner speech", that is, the unspoken speech that is part of a dialog that one carries on with oneself as well as the verbal interaction that was, for Vygotsky, a necessary element in concept development. A concept is not fully realized or understood until it is represented in words.

The hypothesis of the zone of proximal development, popularized as the ZPD or ZoPed, has generated interest mainly in regard to testing and assessment but it has implications for instruction as well. The usefulness of the idea in instruction is in encouraging teachers to think about what a particular child is able to learn at a given time, not depending

only on the current level of development but also on an estimate of the child's capability for moving forward. Vygotsky 's ideas was that what a child can do today with help can be done tomorrow unassisted.

The purpose of this paper, to restate the point, is to present some of Vygotsky's ideas in order to stimulate thinking about concept development and conceptual change. The ultimate purpose is to further understanding of children's thinking in order to improve teaching and learning. Vygotsky was a serious and profound thinker who attacked problems that are of great concern to us today. We do not need another movement among science educators in which people become "Vygotskians" in the manner that some have identified themselves in the past as Piagetians, Neo-Piagetians, Ausubelians, etc. but we should not ignore this rich source of ideas.

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