MAP READING VERSUS MIND READING

Revisiting children's understanding of the shape of the earth

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Abstract. Any study pursuing questions of conceptual development has to position itself with respect to the more general questions of how to conceive human cognition. At one level this study thus presents a contribution to this age-old debate about the nature of human thinking and learning. At another level – the empirical – it provides a discussion of the difficulties that children face when reasoning about the shape of the earth and gravity. The study reported is part of a project that explores issues of how people use physical artefacts, embodying conceptual distinctions of considerable complexity, when thinking and reasoning.

The results suggest that even very young children are familiar with sophisticated knowledge about how to interpret a map. Furthermore, using it as a mediational tool, they can accomplish rather complicated reasoning about the shape of the earth and gravity. This is a demonstration of the flexible and tool-dependent nature of cognition. It is, however, inconsistent with a more formal stage theory or a theory in which children's reasoning is characterised by means of distinctively different conceptions. It is also at odds with a dualist perspective on human cognition in which the embeddedness of physical tools in human reasoning is not taken seriously.

1. INTRODUCTION

For centuries, the question of how to conceive human cognition was an issue that mainly concerned philosophers. During the 19th and 20th century, however, new disciplines emerged, and researchers within areas such as psychology, anthropology, linguistics, neuroscience, artificial intelligence and educational science joined this lively debate. Although its roots go further back, the one perspective that has been dominant in recent decades, or at least up until recently, is the one represented by cognitive psychology. The traditional focus of cognitive psychology is to posit cognition as a fundamentally individual process. The assumption is that human mental functions are located in individuals and can be modelled accordingly as mental entities such as memory systems, thought processes, and cognitive structures.

The empirical approach that resonates with this conception usually explores allegedly basic cognitive and perceptual processes (thinking, memory, problem-solving, perception, etc.) by attempting to unpack the basic mechanisms of mental processes and/or the conceptions of the world that people hold when reasoning. The focus is on cognitive systems and thought processes that – as the metaphor goes –

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underlie reasoning at the level at which it is visible externally in linguistic and physical activities.

A major challenge to this tradition comes from a sociocultural and discursive perspective inspired by Vygotskian and Wittgensteinian views of human cognition and communication (Wertsch, 1991, 1998; Vygotsky, 1986). The sociocultural tradition places human cognition in a historical and situated perspective. Cognition is conceived as a problem of how people use tools – physical as well as conceptual/discursive. This is as much an interactive process as an individual one; in fact, it is very much in the middle as joint and mediated action. And even when reasoning on their own, people do not do this in social isolation - human action is always situated. An important assumption is that such cultural tools form an integrated part of cognitive processes. There is no sense, following such perspectives, in assuming that there is a level of thinking that is "pure" and that underlies reasoning in human practices. We cannot separate thought processes, say in the context of doing geometry or playing chess, from the conceptual tools that are applicable to such activities. Thinking is the use of tools. Or, as Wittgenstein so suggestively put it in the context of the use of language; "When I think in language, there aren't 'meanings' going through my mind in addition to the verbal expressions: the language is itself the vehicle of thought" (Wittgenstein, 1953, § 329).

Although it would be tempting to create syntheses between traditions, our preference is to keep them apart. They build on conflicting assumptions regarding the nature of human cognition and action that have a long history in western philosophy, and the difference between them is of a paradigmatic nature that cannot be easily resolved by appealing to empirical data. However, on some issues the critical differences between these traditions should be explored. The particular area that we will be considering in this context is that of learning and conceptual reasoning. In these areas, the views of these traditions differ very clearly, and these differences have apparent implications for how one conceives human learning and conceptual knowledge and also for establishing what is difficult in such activities.

2. STUDYING HUMAN COGNITION

A critical point of departure in any research on human cognition, and one which deserves to be taken seriously, is that the object of inquiry is somewhat elusive. As scholars we are forced to consider that the observations we are attending to in our analyses are symptomatic and have, as it were, an indirect relationship to what we are interested in. Cognitive phenomena can be described at many different levels, for instance, in terms of neural signals and reactions, blood flow in the brain and all the way up to how people reason and interact in complicated everyday situations. The relationships between these levels are complex, to say the least.

Since the object of inquiry is contested and ambiguous, one has to consider how various paradigms construe their studies, design experiments and relate theory to observation. Rather than arguing about thinking and learning in general, one should scrutinise precisely how the empirical studies are carried out in various paradigms in

order to establish in what sense the observations can be seen as valid indicators of human thought processes and reasoning. When looking at the area that we shall be exploring – children's understanding of the shape of the earth and certain concepts from elementary astronomy (such as gravitation) – these differences between theoretical traditions are obvious. In the following, we shall give a brief introduction to research in this area from a cognitive psychology and sociocultural perspective, respectively. We do not pretend to cover all the research. Rather, in order to address our main question about how children understand the shape of the earth and some related matters, we will give a brief summary of relevant studies with the ambition of illustrating the clear differences in how children's competences and learning trajectories are portrayed. But before embarking on this presentation, we shall say a few words on the notion of conceptual change.

2.1. Conceptual Change in a Sociocultural Perspective

Central to a sociocultural tradition is the idea of mediation and tool-mediated action (Wertsch, 1991). Language, and its conceptual resources, is the most important tool, and it is also unique to the human species – it is the "tool of tools". Concepts and categories thus mediate the world for us in real world activities, and they are, in fact, basic to our perception, reasoning, remembering, and any kind of cognitive activity. Seeing an object as "a square" or "a circle" relies on, and reproduces, a certain, socioculturally generated, set of categories for describing and thinking about objects. However, concepts are not just mental entities that reside inside our heads, they are part of human social practices. People use concepts to do things in a world of physical and intellectual actions; discourse is an important aspect of practical action. The judge uses the concepts of the legal system such as "intent", "fraud", and "assault" when passing a sentence on a suspect. The construction engineer uses the conceptual tools of mathematics, mechanics and other specialised scientific areas when designing a new engine. Thus, and this is one of Vygotsky's (1986) fundamental insights, concepts (or as he referred to them: psychological or intellectual tools) are used by people when thinking (i.e. intramentally) as well as when communicating with each other (i.e. intermentally); thinking in this perspective is conceived as a kind of silent and private dialogue where people use the conceptual resources of their society for reasoning. In this sense, our thinking is sociohistorically produced as we have already alluded to.

So, how does one conceive conceptual development in such a perspective? When regarding concepts as tools (and not just abstract, internal representations of the world), a critical feature of conceptual development is how people come into contact with various kinds of tools that exist in a society. Concepts are elements of discourses that are used in various practices in society. Everyday reasoning relies on conceptual tools as much as does any other kind of activity. But an important arena for the communication of more specialised kinds of conceptual tools is schooling. It is here that the individual encounters scientific (or, more generally, institutional) forms of reasoning that may not be familiar or widely used outside institutional settings. When learning physics, for instance, we have to familiarise ourselves with

new modes of reasoning that build on concepts such as force, velocity, momentum, acceleration and so on that are defined in particular manners. And learning to use these in an insightful manner (which is not the same as being able to define them in a formal sense) can be a long and complicated learning process.

But what, then, is the nature of this process? This is a critical question from a psychological and communicative point of view. Vygotsky (1986) originally suggested that learning and conceptual development could be seen as a process of internalisation by individuals of conceptual tools. However, this is a problematic position, since this formulation somehow recreates a boundary between thinking and communication that Vygotsky was eager to do away with. The point of much of his argumentation is that conceptual tools are used in both these types of human actions, and it therefore seems more fruitful to avoid reintroducing the Cartesian split between "the outside" (communication and physical action) and "the inside" (thinking).

Alternative modes of formulating the processes of conceptual development have been suggested by, for instance, Rogoff (1990) and Wertsch (1998). The traditional preference has been to view learning and conceptual development in terms of appropriation of mediational means. Appropriation, as used here, implies that the individual gradually familiarises herself with a set of conceptual tools and begins to realise how they are used. For instance, Saxe (1991), who studied Brazilian children acting as candy sellers, observed how the young children with a low or no formal education performed complex calculations that involved the awareness not only of proportional relationships between goods and price, but also included consideration of the problems imposed on the activities of selling and buying by hyper-inflation. Appropriation thus implies that the individual is able to reason and act in situations by means of a certain conceptual tool. This does not imply that the tool is appropriated in all its details. This is probably rarely the case. Even if one understands and is able to use the concepts of force or energy when solving physics problems, there are many aspects and potential uses that may take years of further study to appropriate. In a similar vein, the candy-sellers in Saxe's study had not appropriated the concept of inflation in the same sense as an academically trained economist. Yet, in some settings they were able to take this highly complex phenomenon into account in quite a sophisticated manner. In this sense, appropriation implies an increasing familiarity with how a tool can be used for different purposes. Recently, Wertsch (1998) has suggested that it might be useful to make a distinction between appropriation and mastery, a suggestion which is interesting in this context. The latter concept is developed in the context of observations made by the Estonian psychologist Peeter Tulviste (e.g., 1994), who studied the learning of history in Estonia under Soviet rule. In these studies it was shown that the students in school and at universities learned the officially sanctioned explanations and accounts of history and historical development in the Soviet-Marxist tradition without appropriating the conceptual tools or the worldviews these accounts implied. Sometimes the students even mastered these accounts to perfection, but they never used them in any other settings as conceptual tools. So, mastery of a particular kind of tool may be seen as something different from

appropriating a tool in order to actively use it. This is a fascinating perspective on human cognition, but we shall not go deeper into this matter here.

There is another layer to this argument about the tool-dependent nature of thinking, which is essential to the research reported here and has to do with conceptual knowledge. In a sociocultural perspective, the intimate relationship between concepts (i.e. intellectual tools) and physical tools (i.e. artefacts) is emphasised (Bliss & Säljö, 1999; Säljö, 1998). Thus, calculators, calendars, computers, instruments for measuring entities such as distance, volume, pressure, etc. are seen as physical embodiments of human conceptual constructions such as number systems, units of measurement and so on. This implies that when reasoning with artefacts, the tool serves as an aid to thinking in the sense that it represents the world in relevant conceptual categories. This is an important aspect of the role that artefacts play as support and prosthetic devices for thinking, which we will come back to below (see also Wyndham & Säljö, 1998). But before going into this, let us review some of the work done on the particular issue of children's understanding of some elementary astronomical and/or geographical concepts.

3. STUDIES OF CHILDREN'S UNDERSTANDING OF THE SHAPE OF THE EARTH AND GRAVITATION: A COGNITIVIST PERSPECTIVE

The interest in studying children's learning and understanding these matters goes back quite some time. In the cognitivist, and Piagetian, tradition a series of empirical studies have examined the nature of the conceptual problems that children have in this area, and the conceptual change that takes place as they develop (Mali & Howe, 1979; Nussbaum, 1979; Nussbaum & Novak, 1976; Sneider & Pulos, 1983; Vosniadou, 1994; Vosniadou & Brewer, 1992, 1994). A major theme of this line of research has been the illustration of the apparent difficulties children have in understanding that the earth is a sphere. These difficulties were clearly outlined in the pioneering studies by Nussbaum and colleagues during the 1970s. Their findings have later been refined and elaborated but are still, by and large, confirmed by more recent studies. Since these early observations, considerable effort has been put into describing in detail the different constructs children hold (see below), and the transitions in conceptual understanding that take place during ontogenesis. Vosniadou and Brewer (1992), two of the recent leading specialists in this area, suggest that the reason for the problems children have is that information about the shape of the earth contradicts the child's basic ontological presuppositions. That is, the scientifically appropriate model is contradictory to the beliefs held by the children, beliefs based on years of convincing everyday experiences. According to Vosniadou (1994) these experiences form the foundation of our knowledge base. A revision of this base is not easily achieved, and, when this happens, it will have profound implications for subsequent knowledge structures.

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