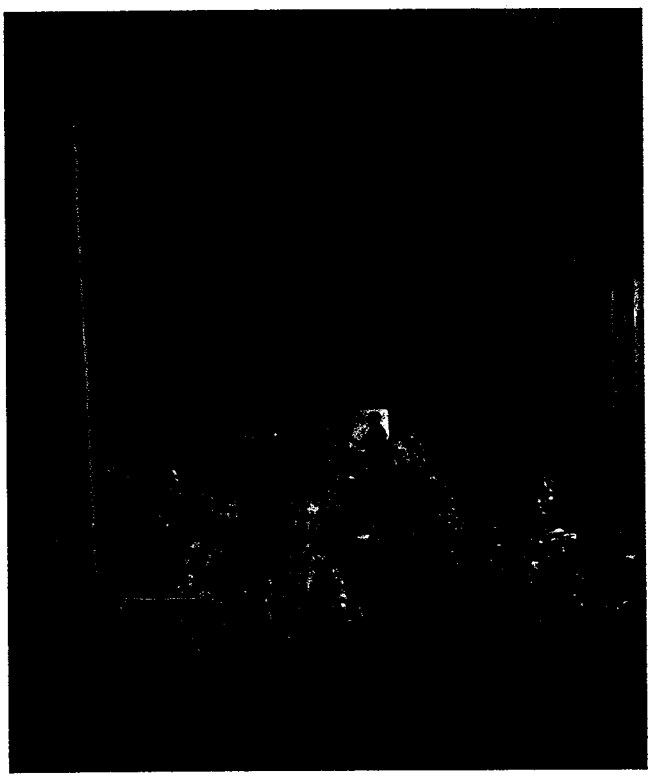
Reconsidering Conceptual Change

Issues in Theory and Practice



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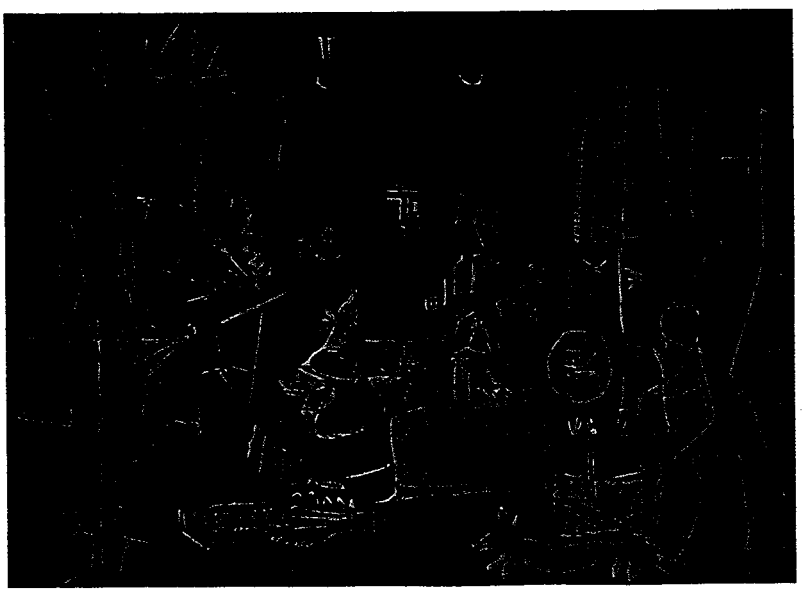

Kluwer
Academic
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Reconsidering Conceptual Change: Issues in Theory and Practice

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KLUWER ACADEMIC PUBLISHERS
DORDRECHT / BOSTON / LONDON

Library of Congress Cataloging-in-Publication Data

ISBN 1-4020-0494-X

Published by Kluwer Academic Publishers,
P.O. Box 17, 3300 AA Dordrecht, The Netherlands.

Sold and distributed in North, Central and South America
by Kluwer Academic Publishers,
101 Philip Drive, Norwell, MA 02061, U.S.A.

In all other countries, sold and distributed
by Kluwer Academic Publishers,
P.O. Box 322, 3300 AH Dordrecht, The Netherlands.

Cover Pictures:

Las Meninas, 1656, Diego Velázquez
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Las Meninas (conjunt), 1957, Pablo Picasso
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Printed on acid-free paper

Printed in the Netherlands.

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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 –

M. Limón & L. Mason (Eds.), *Reconsidering Conceptual Change. Issues in Theory and Practice*, 77-99.

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.

3.1. *Mental Models*

In the cognitivist paradigm, the analyses of conceptual change are closely linked to the assumptions of the existence of mental models. Following Vosniadou (1994), mental models are intermediate phenomena that exist between the overt (verbal or written) responses given by children in empirical studies, and something that she refers to as underlying theoretical constructions or, to use her language, framework theories. Although the specific, individual, mental model may vary in its relations to the underlying structure, it is believed that the generic aspects of a mental model can provide information about these underlying so-called framework theories.

> Mental models are dynamic and generative representations which can be manipulated mentally to provide casual explanations of physical phenomena and make predictions about the state of affairs in the physical world. It is assumed that most mental models are created on the spot to deal with the demands on specific problem-solving situations. Nevertheless, it is possible that some mental models, or parts of them, which have proven useful in the past, are stored as separate structures and retrieved from long-term memory when needed. (Vosniadou, 1994, p. 48.)

Having taken a brief look at the conceptual foundations, we shall now, following our previous argumentation, take a closer look at some of the elements of what has actually been studied in this line of research.

3.2. *Mental Models and Children's Reasoning*

The methodology used in these studies varies, as do the modes of analysing data. One prominent method for generating data on children's mental models/framework theories, though, is the structured interview in the Piagetian tradition of the méthode-clinique (Piaget, 1929). The nature of the responses generated has also varied. In some cases, children have responded verbally, in other cases they have been asked to draw a picture or even to construct physical models using clay or other resources. At any rate, the basic assumptions are that the questions have a potential to unravel the mental models students have.

The general results obtained within this tradition of research on children's understanding of the earth can be summarised by means of the study reported by Vosniadou and Brewer in 1992. Here the "mental models of the earth" that children use are depicted as illustrated in Figure 1. At one end we find various kinds of flat entities that are described and/or drawn by children. These are followed by so-called

Figure 1. Mental models of the earth.
Adapted from "Mental Models of the Earth: A Study of Conceptual Change in Childhood" by S. Vosniadou and W. F. Brewer (1992), *Cognitive Psychology, 24*, p. 549. Copyright © 1992 by Academic Press. Reprinted by permission.

combined models (where the earth may take on different shapes) to hollow spheres, and, finally, we end up with versions that are close to the scientifically correct one. According to this cognitivist perspective, all children seem to follow the same line of development. The demands placed on them – the cognitive conflict – to integrate the culturally accepted view of the earth as a sphere with their everyday experience force children to go through a number of steps in which they hold different conceptions of the earth. What is not entirely clear is where these models come from, an obscurity that seems to be a general problem for this tradition. In fact, as it has been argued, "cognitivism remains perennially unable to resolve such thorny problems as the origin of ideas or concepts" (Gergen, 1985, p. 270). In this case, it seems as if the models are constructed anew by each child on the basis of personal experience and essentially without cultural support. The ontological presuppositions (i.e. the framework theories) are constraints that the children simply have and that they have to struggle with.

The procedure of inferring a level of mental models on the basis of observed responses is not uncommon within the cognitivist perspective. In fact, Gardner (1987) describes this mode of working as one of the major accomplishments of cognitive science. Nevertheless, we believe there is good reason to be cautious. This practice of introducing such an intermediate level in explanations implies a shift from specific observable events to generalisations and abstractions on a totally different level, a jump between logical types (Bateson, 1972, 1979). Also, such a strategy introduces not only theoretical and epistemological problems but also ontological ones; what is the ontological status and psychological reality of mental models?

Having pointed this out, we would like to emphasise that we do not deny that the children in the studies commented on above are reasoning *in terms of*, for example, a disc shaped or hollow sphere earth. But we are far less convinced that there is anything to be gained by saying that children *have* mental models of these kinds. We believe that a distinction can be drawn between having mental models and reasoning in terms of them. The latter assumption avoids making ontological assumptions and makes a clear distinction between the researcher's perspective and analytical tools on the one hand, and mental models that children allegedly have on the other.

3.3. *Situating Children's Reasoning in the Interview Setting*

A point that needs to be emphasised here is the fact that the children in the cited studies do not reason in a vacuum. In many studies (Mali & Howe, 1979; Nussbaum, 1979; Nussbaum & Novak, 1976; Sneider & Pulos, 1983; Vosniadou, 1994; Vosniadou & Brewer, 1992) participants have been asked to express themselves using physical objects, pictures or drawings (see Figure 2).

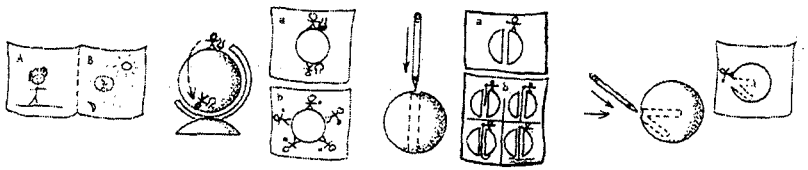

Figure 2. Objects used in interviews.
Adapted from "Children's Cosmographies: Understanding the Earth's Shape and Gravity" by C. Sneider and S. Pulos (1983), *Science Education, 67*, p. 209. Copyright © by John Wiley & Sons, Inc. Reprinted by permission.

The status of such physical artefacts and drawings is not taken up in any of these studies. The drawings, for instance, are only regarded as expressions of underlying conceptions, and never as resources in themselves that contribute to and co-determine the process of reasoning.

Very few of these studies present their data in a manner that makes it possible to discern how these drawings are produced and what role they play in children's reasoning. However, one point that is worth exploring is if children can be assumed to always be clear about the relationship between the drawing and what it is supposed to model (the earth as an astronomical object). It does not seem far-fetched to suspect that the relation between the (physical) model and its referent is lost from time to time in these interviews. An observation from Vosniadou (1994) illustrates this. Here, we find the girl Kristi being asked to draw the "real shape of the Earth." Kristi draws a circle and is then asked to reason about what happens if one walks in a straight line for many days.

> Kristi (first grade)
> E: What is the shape of the Earth?
> Child: Round
> E: Can you make a drawing which shows the real shape of the Earth?
> C: (Child draws a circle.)
> E: If you walked and walked for many days in a straight line, where would you end up?
> C: You would end up in a different town.
> E: Well, what if you kept on walking and walking?
> C: In a bunch of different towns, states, and then, if you where here and you kept on walking here (child points with her finger to the "edge" of the circle which she had drawn to depict the Earth) you walk right out of the Earth.
> E: You'd walk right out of the Earth?
> C: Yes, because you just go that way and you reach the edge and you gotta be kinda careful.
> E: Could you fall off the edge of the Earth?
> C: Yes, if you were playing on the edge of it.
> E: Where would you fall?
> C: You'd fall on this edge if you were playing here. And you fall down on other planets.
>
> (From Vosniadou, 1994, p. 51.)

In this example, Kristi makes active use of the drawing as a resource for her reasoning as can be seen. She repeatedly points to it to make explicit and support her arguments. However, what is interesting here from the point of view of her cognitive performance is that this drawing of the earth is nothing but a thin line; it *de facto* contains something that in some sense is the "edge of the earth." If we assume that Kristi for the moment is talking about her drawing, and temporarily disregards the fact that it is a model of something else, it seems quite logical to assume that one can fall off the edge. Also, the approach of the interviewer in this excerpt is anything but neutral and passive (which is how interviewers in research generally are described as). Rather, s/he can be read as signalling that s/he is not satisfied with the response given by the child in line six ("You would end up in a different town"). By insisting on this topic of what would happen if "you kept on walking and walking" in her next contribution, the child might be seen as being provoked into saying something different rather than merely repeating the same response.

In our view it is essential not to go abstract at too early a stage. Children's reasoning in situations of this kind are better studied as situated practices where the dynamics of the context, the dynamics of the interviewing, and the tools available, are decisive for what children say or do.

4. STUDIES OF CHILDREN'S UNDERSTANDING OF THE SHAPE OF THE EARTH AND GRAVITATION: A SOCIOCULTURAL PERSPECTIVE

Physical tools originate in collective cultural practices, and human cognition is socialised through participation in activities where tools are used for particular purposes. A very important dimension in sociocultural development is the increasing sophistication of tools that occurs over time. Powerful intellectual distinctions and resources are built into tools that are used for a wide range of purposes when performing activities such as calculating, navigating, communicating, reading, analysing substances at microlevels, playing games and so on.

The attitude towards thinking that characterises this perspective thus emphasises the intimate links between cognition and the use of tools in situated practices. There is no such thing as "pure" cognition that can be accessed *per se* as we have already pointed out. Even in interview situations, such as the ones commented on above, the terminology used, the manner in which questions are formulated as well as the drawings and artefacts used, mediate people's reasoning. To reason with a physical object as a model is one thing, to reason without such resources represents another situation with very different cognitive demands.

This view of cognition as the use of tools was the background of the study on children's conceptions of the shape of the earth and gravitation carried out by Schoultz, Säljö and Wyndhamn (in press). The main idea behind this study was to analyse how children reason about elementary astronomical concepts when doing this in the context of an artefact, a globe. The interviews were conducted in a Piagetian fashion and to a large extent modelled on the studies in the cognitive tradition summarised above. The children (aged 6 to 11 in grades 1 to 5) were first asked to identify and name the object in front of them (which all children did

without any problem). All children also realised that the globe was a model of the earth. The results show that when using the globe as a resource for reasoning, the children were surprisingly knowledgeable and sophisticated. Even amongst the youngest, there were several who argued in terms of a concept of gravity (sometimes without using the term) as an explanation of why things fall to the ground. None of the children considered it possible to fall off the earth. Even when put under considerable pressure by the interviewer, who pointed at countries such as Argentina and Australia visibly located on the downside of the globe, and explicitly asking if people would not fall off, did any of the participating children agree to the possibility that people "down under" might fall off the earth. None of the children suggested that the earth might be flat, hollow or take on any of the shapes that have been found in previous research (see Figure 1).

The authors conclude that the differences in outcome testify to the mediated nature of reasoning. The globe was obviously a familiar artefact for the children. When reasoning with this tool as a resource, the children were in a completely different situation as compared to when being interviewed or when making drawings on their own. For instance, they could read the names of the countries on the globe, and they knew from other sources (media and friends) that people live in Australia and other countries that appear to be on the downside of the earth. This information was enough for them to realise that people do not fall off the globe irrespective of whether they could explain why this does not happen. The globe in this sense is doing concrete discursive/cognitive work by supporting certain kinds of reasoning and by positioning the children differently in comparison to a situation without such a tool. It served as an orienting device that gave the children something concrete to refer to when reflecting on the questions. It also served as an aid to memory by operating as an inference-rich tool that reminded them of other sources of information.

Carrying this line of reasoning further, one conclusion is that if one considers the unit of analysis to be *children operating with mediational means* (Wertsch, 1998) in the form of intellectual and physical artefacts, the image of children's knowledge that is produced in empirical research will be very different. In the study by Schoultz, Säljö and Wyndhamn (in press) above, basically all the conceptual problems that have been pointed to in the cognitively grounded research seem to disappear when the globe is available. Cognitive development cannot be exclusively, or even predominantly, conceived as changes in mental models or cognitive structures. Rather, it seems better captured in terms of the increasing mastery of mediational means that might be intellectual or physical, or, as in the case with the globe, that are simultaneously both. Artefacts thus *re*-present in material form certain conceptual distinctions, and this is precisely why the globe served as such a powerful tool for thinking for the children.

An interesting question in this perspective, then, is to what extent the children's considerable sophistication when reasoning with a globe present can be seen as limited to the use of this particular tool only. The three-dimensional nature of a globe makes it a rather powerful model of the earth. What will happen to their reasoning if they encounter these issues of the shape of the earth and gravity in the context of another mediational means, the map? This is the question that will be

pursued in the present study. But before presenting our analysis of how the children reasoned with the aid of a map as an intellectual tool, it is helpful within a sociocultural perspective to consider somewhat the sociogenesis of this particular tool and the conventions built into it.

4.1. The Sociogenesis of Maps

Every artefact has a history. In the case of maps this sociogenesis is quite complicated, and it is related to the development of concepts, insights and improvements in representational technologies. The interesting point from a sociocultural perspective is the extent to which these concepts and distinctions are perceived by the present-day user, and how they are appropriated when using the tool.

In the history of the Western World we know that the earth was recognized as being spherical at about the time of Aristotle (384-322 B.C.) (although this did not become the accepted view until much later in history). The evidence for this conclusion varied. From an empirical point of view, it was evident that ships seemed to "come over" the horizon when sailing away or towards the observer. From the point of view of ideas and cultural beliefs, there was an assumption that the sphere was the most perfect form. Early calculations of the size of the earth were carried out by both Eratosthenes (ca. 276-195 B.C.) and Posidonius (ca. 130-50 B.C.). Although the methods used were correct, the assumptions and the precision of the observations were not. These errors, however, tended to compensate each other. Since the calculations were based on a unit called *stadia,* we cannot be entirely sure of the exactness of the estimations. It seems, though, as if they overestimated the size by only 12 to 15% (Robinson, Sale, & Morrison, 1978).

The early history of the representational tool that we know as maps seems somewhat disputed. Some (see Harvey, 1980) claim that the topographical map developed quite late in our cultural history, while others (see Fremlin & Robinson, 1999) maintain that the topographical map was conceived already in prehistory. Irrespective of these differing views, one can find occasional references to maps in the classical Greek literature. This, according to Robinson, Sale and Morrison (1978), makes it possible to infer that mapping was not an uncommon practice at this time. On the other hand, none of these maps appears to have survived. The writings of Claudius Ptolemy (ca. 90-160 A.D.), however, did survive. In his production there was one book, simply called Geography, which covered what was known about the earth at the time. Among other things, the Geography included a treatise on cartography in which Ptolemy described how maps should be made. He commented on the problems of presenting the spherical surface of the earth on a flat sheet, and he clearly recognised the inevitability of the deformation that must follow in such a process (Robinson, Sale, & Morrison, 1978). Although refined and developed throughout the centuries, many of the techniques used in the construction of maps of the earth seem to have been recognised rather early.

Maps of today carry with them many conventions. Some of these have changed through the course of time, others have stayed more or less the same for long

periods. In medieval times, most maps of the known world – *mappa mundae* – were drawn with Jerusalem at the centre and paradise at the top. Paradise was believed to be found beyond the farthest area known, the Orient. It is from this practice that we have derived the expression "to orient" a map. Today we orient our maps towards the north instead of the east, but the practice as such is the same. Another example is given by the geographical coordinate system, which is the procedure of dividing the sphere into latitude and longitude. This system was introduced some 2200 years ago and has not been changed since (Robinson, Sale, & Morrison, 1978).

4.2. Method

The present study, thus, is a continuation of the interest in how children reason when using culturally meaningful mediational means. The map (see Figure 3) we have used thus gives a two-dimensional image of the earth. The map is taken from a type of atlas frequently used in schools.

Figure 3. Map used in interviews (size 40 x 18 centimetres).

4.2.1. Participants and Analysis

The empirical data were collected through interviews in schools. Eighteen children, aged 7 to 9, participated. In accordance with the study by Schoultz, Säljö and Wyndhamn (in press), the interviews were conducted in a Piagetian fashion and lasted between 10 and 20 minutes. The central questions were approached by talking about different countries, colours on the map etc. The interaction between the interviewer (JS) and the child was audio recorded and later transcribed in full. The analysis is based on the transcripts.

4.3. Results

In this first part, we will show how the interviewer and the children reach a common understanding of the artefact and the purpose of the encounter. This is a coordinating activity that precedes the discussion of the main topic of the interview – the questions about shape and gravity. The precise manner in which the map functions as a prosthetic device for reasoning will be discussed in the second part.

4.3.1. Coordinating the Activity: Identifying the Artefact and Contextualising the Issues

Being introduced to the atlas, the children thus face a complex artefact with a long history. The artefact is well known to all of them, which *per se* is a sign of their position in a sociocultural sense. But in spite of the familiarity of the artefact, it is not clear to the children how it is going to be discussed in the interview setting, especially at the start of the encounter. There are many options. The artefact in front of them could be temporarily discussed as a book of a certain type, that is, one could focus form rather than content. It could also be discussed as a map with different colours, names and states, etc. A third option would be to talk about the artefact as a model of the earth.

Although one might refer to these three approaches as "levels of abstraction", they are better conceived as different forms of situated talk relying on different interpretations of what is of interest. These three alternatives are all reasonable manners of discussing in a school setting, and there is initial uncertainty when the interviewer asks the question "What is this?" with reference to the artefact. The problem for the child is to identify what is the expected type of discourse.

Excerpt 1. David 2nd grade

1	I:	Do you know what this is?
2	David:	A book
3	I:	And what is this supposed to be?
4	David:	A globe
5	I:	A globe, do you recognise any countries?

Excerpt 2. Anton 1st grade

25	I:	But now Anton I'm going to ask you some questions. Then, of course, you know what this is?
26	Anton:	A map
27	I:	What does it represent?
28	Anton:	The whole earth
29	I:	The whole earth. Do you recognise any places or countries or something you ... you can read if you want to

Excerpt 3. Anna 2nd grade

1	I:	What is this?
2	Anna:	It's the earth
3	I:	Why is it drawn like this? [Points at the corners of the map]
4	Anna:	It's round

We emphasise this problem of the choice of discourse in order to illustrate that the multitude of manners in which it is possible to carry out a discussion is a concrete problem for the child. The difficulty with the questions asked does not reside solely in what the object in front of the children *is* in a factual sense or the conceptual issues that are involved in interpreting a map. The problem for the child is also to identify what the questions are all about, and how one is to contribute to the conversation. This is thus primarily a communicative problem and not a conceptual one. This is illustrated in Excerpt 4, where the uncertainty expressed clearly refers to the interview-situation.

Excerpt 4. Paul 2nd grade

3	I:	Do you know what this is?
4	Paul:	Nope
5	I:	This?
6	Paul	A globe ... noo
7	I:	Is it that?
8	Paul	Yes
9	I:	If we assume that this is a globe, why is it drawn round like this?
10	Paul:	The globe is round

When being asked if he knows what is in front of him, Paul responds with an initial "Nope." This cannot be taken as evidence of the fact that he does not know what the artefact is. Rather, it seems likely that he is uncertain as to what is a relevant way of talking in this situation. After the following utterance by the interviewer, he argues that it is "a globe." We have to be aware of the fact that an interview is a communicative and interactive project. Without appropriate guidance from the adult, who is the dominant party in this interaction, the child will often respond in a vague and non-committal manner (which is also a common strategy in other conversational settings when people are uncertain what the purpose of an utterance is).

It is an interesting problem if the ability to identify an artefact as a "globe" or as the "earth" is itself indicative of having a particular mental model. There is, of course, always the option of making such an assumption by introducing an object of inquiry at this intermediate level. But the critical question is what is gained by such an explanation. To refer to these modes of talk as indicators of "conceptions" or "mental models", and to locate them in the head of the individual, will not help us understand why people choose one or the other.

If we instead focus on the actual interaction, the choice of explanation should be made on the basis of what can be observed. We believe that the manner in which the topic is discussed is not a discrete act but a process that unfolds, a process that is

both possible to study and to understand. Dialogical as it is, in the sense of building on the contributions of both parties, the interaction can be conceived as a mode of talking and thinking that is not only temporally distributed, but also distributed among the participants. This makes the method of looking for conceptions 'behind' answers even more problematic. If not even answers can be fully attributed to individuals, how could we possibly consider them primarily as mental constructs and give them priority as explanatory concepts?

Excerpt 5. Carl 3rd grade

5	I:	It's difficult to know. Well I have a question for you. What is this?
6	Carl:	The earth
7	I:	Does the earth look like this?
8	Carl:	Yes, perhaps
9	I:	Perhaps, it does. What does the earth look like in reality?
10	Carl:	Round
11	I:	Round like a ball
12	Carl:	Mm
13	I:	But if you're going to make it like a map you have to do it like this right
14	Carl:	Mm
15	I:	And then you have to make some bends like this. Why does it look flattened? Why does one draw it like an egg do you think?
16	Carl:	You can look at the whole around
17	I:	No, that's right you can't see the backside otherwise. You can imagine taking the ball and cutting it open

Excerpt 5 illustrates what can be seen as a distributed answer. We believe that it is more appropriate to say that the answer to the question posed in line 5 is to be found between lines 6 and 17 rather than in line 6 alone. The question initiates a dialogue, and the genuine answer sought for is not merely what kind of label one would put on the object, but rather how one should conceive of this object and its properties/functions. In this passage, it is clear how the interviewer is an active co-constructor of meaning, and that he sometimes elaborates the children's contributions considerably. In some traditions, this would probably be regarded as an improper procedure for an interview, a confounding variable as it were. From our dialogical perspective on communication, however, we regard this as a natural and realistic attitude to interaction, perhaps even necessary in order to maintain a joint focus. The ideal of the passive partner in interview research probably hampers the progression of the interview in many cases.

Furthermore, participation in certain discursive practices presupposes that one focuses on some aspects. When talking about a map, the thickness of the paper is seldom relevant. Varying artefacts and discourses also presuppose familiarity with certain concepts or pieces of information. On a political map, for instance, colours signify something different than topographical cues. This kind of awareness of the

specific rules that should serve as premises when reading maps is an important feature of a person's ability in our material. It is most striking how conscious the children seem to be of the artefact as being a form of representation. Bearing in mind the young age of the participants this is not something that should be taken for granted, rather it is something that should be looked into more carefully. It is important to consider how the artefact supports thinking. For the interviewer and the children to end up with a shared understanding of the object under scrutiny, however, some time needs to be invested. Excerpt 6 provides a prototypical example of what this process looks like.

Excerpt 6. Tim 3rd grade

3	I:	I would like to ask you about this. What is this?
4	Tim:	A map, the globe
5	I:	Why does it look like this? [Elliptical]
6	Tim:	Because it's round
7	I:	Does the earth look like this?
8	Tim	Yees
9	I:	So it does
10	Tim:	But it's more round
11	I:	And then?
12	Tim:	It's more even, not long like this
13	I:	No, why do you think you draw it like that and not rounder? Why can't you do that?
14	Tim:	Because you can't draw the backside

In Excerpt 6, the interviewer and the child come to the conclusion that they are dealing with a map of the earth projected on a flat piece of paper. We can follow the discussion on the transforming processes involved in producing this kind of projections. When dealing with an object like this, the participants can make active use of its physical properties, something that is done in line 12. Here, Tim refers to the stretched look of the map and calls the interviewer's attention to the fact that this is a by-product of the process of mapmaking. By using an observable property like this, he shows awareness of some of the conventions of map-making, and he is also very clear about the distinction between the model and what the earth looks like as a physical object.

Although the interpretations of the questions may differ between the interviewer and the children, as we will discuss below, the referent of the map as a model of the earth remains a reasonably shared focus throughout the discussion. However, we should like to emphasise that this coordination of perspectives is an achievement (Rommetveit, 1988, 1992), and not something that can be taken for granted. The children can be made to share this perspective, but it has to be established as the one intended for this particular discussion. However, this can be efficiently done without the interviewer adding further pieces of information or explanations.

4.3.2. Cognition and Reasoning: Utilizing the Artefact as a Cognitive Prosthesis

As we have shown, the interviewer, in co-operation with the interviewees, initially establishes the artefact as being a map of the earth and that this is what is of interest in the following discussion. This is followed by a discussion of what the different colours on the map signify. When this is over, the interviewer follows his agenda and turns to the main problem of the interview, namely if one can fall off the earth (which, in a sense, is the question about gravity, framed in a particular way borrowed from previous research). The question is paraphrased as whether humans can inhabit the whole earth (or, in a later step, if they can live "down there"). Although all the children answer the initial query with a unanimous "no", the answers do not mean what they at first would seem to mean. The question presumes that one talks about the earth as an astronomical body, where gravity is the principle explaining why objects fall to the ground and why there is no up and down on the earth. Scrutinising the children's responses, however, we find that they bring in new topics such as political and geographical conditions. This is a shift in conversational focus that illustrates the polysemic nature of the questions. A typical example is given by Excerpt 7.

Excerpt 7. Eric 2nd grade

43	I:	Can people live down here, then?
44	Eric:	Nope
45	I:	Why not?
46	Eric:	Because it's so far down
47	I:	Why isn't that possible, then?
48	Eric:	Mm perhaps you get an inflammation of the ear
49	I:	Why would they get an inflammation of the ear down here, then?
50	Eric:	Perhaps it's cold

What this and the following excerpts illustrate is a conversational problem that Lemke (1990) refers to as a matter of "thematic continuity" in interaction. The interviewer takes the astronomical framing of the issue for granted (the interview is organised so as to be about the earth as a celestial body and about gravity), while the children choose other categorisations. In Excerpt 7 above, Eric refers to unfavourable climatic conditions and the risks of catching ear infections as a reason for why one cannot live "down there." In the following excerpt, the boy Jakob in a more general sense refers to the fact that there are places where it is too hot or too cold to live.

Excerpt 8. Jakob 3rd grade

37	I:	Mm, can people live all over the earth? What do you think?
38	Jakob:	Nope

39 I: Where can people not live?
40 Jakob: Where it's cold
41 I: Anywhere else?
42 Jakob: Where it's hot

From Excerpts 7 and 8 one could argue that the children never understood the meaning intended by the question. And in a sense we agree, they did not overtly consider the option that one cannot live on the down side of the earth. There is a clear difference in how the interviewer and the interviewees read these questions. But, it is also quite possible that the children consider the option that one could fall of the earth as absurd. They therefore construe, on the spot, a response to why one cannot live everywhere that might serve as a reasonable suggestion.

The line of reasoning found above could be seen as an issue of the problems the children have with identifying the precise nature of the topic of discussion and how to proceed with the dialogue. This problem of thematic continuity, thus, is not located in the conceptual knowledge of the child. It seems better conceived as a problem that has to do with the fact that the agenda is partially hidden from the child, while it is clear to the interviewer. The problem of thematic continuity should therefore preferably be studied from both an interviewer and child perspective, respectively. The children are not given a sufficiently clear indication that they should stick to the astronomical framing.

Being engaged in a conversation obliges the participants to follow a number of more or less tacit interactional rules. Mastering these rules is an important element of the process of becoming a competent member of our society. For example, failing to provide a response when being asked a question is a sharp violation of these rules. Another important rule is to regard our conversational partners as being intelligible and coherent. In an interview-situation these guiding principles tend to be of utmost importance for the interviewee, sometimes followed *ad absurdum*. What we find, then, in this material is the children proving to be qualified language users. When the interviewer hints that there exists a problem, the interviewees read him as being intelligible. The only way they can do this, supposing that they *do not* hold it possible that one can fall off the earth, is to change the topic or extend it in a reasonable direction and this is precisely what the children seem to be doing in the excerpts we have used.

A further point, which supports our line of reasoning, is that when the question about gravity is explicitly expressed, not a single child accepts the claim that it is possible to fall off the earth. On the contrary, most children show a remarkable ability to participate in a discussion on this difficult topic and to make meaningful contributions. Excerpt 9 illustrates how educated a conversation a pupil in the first grade can accomplish if only given a bit of support in the interaction.

Excerpt 9. John 1st grade

124 I: Of course one can live in South Africa, one can live in South America. Don't you fall off the earth down here then?
125 John: No

126 I: You don't
127 John: If you come like this outside you don't fall off if you walk outside the earth
128 I: But if you walk far down here in the south, then? Don't you think it's strange that you can live down here? What if they just slip and fall off the earth?
129 John: No, they won't do that
130 I: Why won't they do that then?
132 John: They think they're walking in their way. They're more used to walking like that or something
132 I: Oh, I see
133 John: But actually you walk ... it feels as if you walk straight ahead and then you walk around the earth if you go too far
134 I: So you can't fall off the earth?
135 John: No, it's almost as big as anything

Given all the research within the cognitivist perspective illustrating the apparent difficulties children have with understanding the shape of the earth and gravity, one would not expect to find any satisfactory explanations of why it is impossible to "fall off" the earth. But notice in line 133 how seven-year old John in a very exact way resolves the supposed conflict between the information about the shape of the earth and his "basic ontological presuppositions" (Vosniadou, 1994, p. 49). He is clearly able to distinguish between what happens on a psychological or personal level and what happens on a physical level: one can walk "straight ahead" and still walk "around" the earth. This is quite an amazing insight for a seven-year old.

Having arrived at this point, we will conclude this part by commenting on one general feature of the empirical material. Our impression is that in order to maintain the dialogue the participants have to reach temporarily shared contextualisations (Rommetveit, 1992). The children, operating under the specific conditions provided here, have to coordinate their way of conceptualising the activity with the one represented by the dominant party in the interaction. Posing a question is maybe not enough to put the child in a communicative situation where the contextualisations of what is talked about are sufficiently shared. Perhaps this problem of coordination is a more important feature of learning contexts than is generally recognized; it is by being supported in the complex task of adopting and sharing specific perspectives that one learns to talk and think under the guidance of a more experienced partner.

5. CONCLUSION

The results of this study in many respects confirm the general observations made in the previous work where the globe was present in the interview situation. The conceptions about the earth as a flat object, as hollow, etc., do not appear in this material either, in spite of the fact that this study involves the use of a two-dimensional artefact. The claim that children hold such mental models (or framework theories) seems questionable and appears primarily as a product of the

methods used. When children are interviewed without any support in the form of a meaningful artefact, they obviously express views that disappear completely when there is a map present.

In a similar vein, none of the participants in this study accept the view that one can fall off the earth. Not even when being explicitly asked, in quite a provocative manner, what happens if one is "down under" on the map do they suggest that this would be possible. This is a strong indication of the familiarity on the part of the child with the map as a cultural artefact and of the efficiency with which it serves as a prosthetic device for reasoning. What is it, then, that so clearly differentiates this study from the studies made within the cognitivist perspective? Methodological differences regarding what are legitimate inferences of what children mean by what they say aside, two major factors stand out. The first element is the use of a physical artefact with a long history. The map is a powerful device that carries a number of conceptual distinctions with it, many of which may be totally unknown to the children. With a more competent conversational partner to help them, though, this map functions as an effective resource for reasoning. The map helps create what Latour calls "a meeting ground, *a common place*" (1986, p. 8). Due to its "optical consistency" in Latour's sense the two-dimensional surface of the map will provide the same "windowpane" for any observer who is familiar with this particular piece of technology. The map affords viewpoints and information. In this study, it is clear that both children and interviewer make active use of this optical invariance as a resource for their reasoning (see Excerpts 3, 4, 5, 6 & 9). They go back and forth between thinking, talking and consulting the artefact.

The use of a physical artefact alone, however, is not a sufficient condition, as is illustrated by the multitude of objects used by, for example, Sneider and Pulos (1983) (see Figure 2) in their study. The children also have to know what they are supposed to talk about. The second factor, differentiating this study from many others, is therefore associated with the way the artefact, and the whole interview situation, is framed (Goffman, 1974) in a communicative sense. How one is supposed to talk about an object is not self-evident, which is illustrated in Excerpts 1 to 3. It is necessary that the interviewer and the interviewees reach some sort of common understanding of the artefact and, in this case, its relation to its referent. Given the uncertainty initially expressed by most children regarding the status of the artefact and the point of the interview-situation as such, we believe that the map can be seen as a "boundary object" (Star & Griesemer, 1989). The concept of "boundary objects", as developed by Star and Griesemer, is an attempt to describe how objects may help create mutual comprehensions across intersecting social worlds.

> This is an analytic concept of those scientific objects which both inhabit several intersecting social worlds *and* satisfy the informational requirements of each of them. Boundary objects are objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across time. They are weakly structured in common use, and become strongly structured in individual-site use. (Star & Griesemer, 1989, p. 393.)

Although boundary objects have different meanings in different social worlds their structure is common enough to more than one world, to make them recognizable. In their description, Star and Griesemer portray four different types of boundary

objects. Of these, the *ideal type* is the one most in agreement with our map. The ideal type of boundary objects, such as a diagram or an atlas, is abstracted from all domains and may remain rather vague. Due to this vagueness it can be adapted to a local site and function as a means for communication. This adaptation of the map to the local context is exactly the process we have observed (see Excerpt 6), and we regard such adaptation as necessary for the communication to function properly. Following Star and Griesemer, "boundary objects act as anchors or bridges, however temporary" (1989, p. 414) between contexts and persons, and this, we believe, is the reason why the interviews in this study have a rather stable character, why the relation between the map and the earth can be sustained in spite of the low age of the participating children.

As has already been pointed out above, the main theme of this study is the assumption that there is no baseline for cognition. Although we admit that there are phenomena that can be labelled *mental processes*, we cannot accept the claim that these are possible to study independently of cultural tools. There is nothing to be gained by positing such a level of inquiry as the one implied by a notion of pure cognition underpinning our thinking. Our mental functioning is irrevocably intertwined with a vast array of cultural tools. When we, for example, do mental calculations, no visible or otherwise apprehensible borders can be found between the human as an "information processor" (Ashcraft, 1994), and the multiplication table as a cultural artefact. This is the reason why we prefer to change metaphors and, instead, talk about cognition as the use of tools.

Although it has been common practice in the educational area to test the abilities of pupils, stripped of most of their ordinary tools, we do not feel the need to import this thinking into scientific inquiries. On the contrary. There is no sense in saying that functioning without support in the form of physical artefacts is the more natural or basic state of human cognition, or that such an approach provides a more correct measure of an individual's competence.

From our perspective, an important part of cognitive development is the gradual appropriation and/or mastery of mediational means. Early in this process, when the mediational means are unfamiliar and still poorly under control, one is more open to influence and more in need of communicative support. Under such conditions, the unit of analysis (children operating with mediational means) is in a sense less stable or less coordinated. This is why studies, using somewhat different methods, can come up with results that vary. Provided with various forms of artefacts and varying levels of support, children of the same age span will present responses within a very large spectrum. This is not particularly surprising.

Consequently, we do not propose that the children in this study have presented their "normal" functioning or that this is necessarily how they reason in their everyday lives. We would, rather, like to point out the flexible nature of human cognition and the potentialities that exist in this area; how understanding and reasoning are not so easily confined within the boundaries of a single individual, but how mental activities instead, metaphorically speaking, interact with artefacts and other people. The distinction between cognition of individuals, communication between individuals and tools must be regarded as blurred. What we have shown is that given favourable conditions even young children *can* accomplish rather

complicated forms of reasoning and make distinctions between what they see in front of them and what applies in a physical world and when looking at the earth as an astronomical object. In some fascinating sense, the distinctions made by these children would have been impossible for the most advanced scholars a few hundred years ago to make. This is a strong indication of the intimate links between culture and human reasoning, and, ultimately, between culture and human development.

ACKNOWLEDGEMENTS

The work reported here has been financed by the Swedish Council for Research in the Humanities and Social Sciences through a grant to the project Information technologies as prosthetic devices for cognition and communication. A sociocultural analysis of computer-mediated learning in science instruction.

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