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Seeing Through the Screen: Human Reasoning and the Development of Representational Technologies

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Material artifacts play a prominent role in most social practices. Humans learn and develop not only in a world of social relationships but also in a world of things. In spite of the ubiquity of physical objects in all that we do, most theoretical accounts of learning and development downplay or even disregard the fundamental manner in which our actions, insights, and modes of knowing are dependent on familiarity with and use of things. By failing to consider the role of such resources in human activities, most theoretical perspectives simultaneously downplay the role of artifacts in the cumulation of knowledge and skills in society at large.

In addition to the centrality of tools in most human practices in general, a large portion of the objects that figure in children's activities (e.g., various kinds of toys, games, books, computer software) in many societies is specifically manufactured with the ambition of developing cognitive and communicative skills of various kinds.

In a sociocultural perspective (Vygotsky, 1986; Wertsch, 1998), artifacts can be seen as objectifications of human intentions and insights. "What the child learns to see, to touch, to move around, to throw is a range of artifacts that already has a human significance for even the very young child" as Wartofsky (1983, p. 13) put it. As children relate to these objects in social practices, caregivers will provide guidance where the signifying functions of artifacts are central. In guided participation (Rogoff, 1990) children thus appropriate socioculturally prominent interpretations of the world around them through the use of artifacts. They learn about such diverse matters as techniques for counting, writing, and drawing, about gender roles, and how to compete in various kinds of games. Cultural psychologists and sociocultural theorists argue that cognitive development is not universal but will depend on the specific social practices and the tools and technologies that children are exposed to and learn to use as mediational means (Cole, 1996; Leont'ev, 1978; Vygotsky, 1986).

In a technologically complex society, children develop skills in using a range of symbolic artifacts. These symbolic tools are intimately related to physical tools. In fact, it is in most cases not easy to make a distinction of this kind. Written language and counting systems are obvious examples of symbolic systems that are implemented by means of physical objects. However, there is a wealth of artifacts that embody symbolic systems and notations including maps, graphs, charts, drawings, and tables, to mention some examples. In a historical perspective, the trend seems to be fairly clear; people are exposed to an increasing number of such artifacts, and they are expected to be competent users of them at an early age. As we examine further in this chapter, such intellectual tools must be seen as mediating perceptual activity. Human's very seeing and understanding of the world are in a fascinating sense related to the development of symbolic and technological systems.

In what follows, we explore two issues in the context of children's use of the particular kinds of representational tools that are built into information technology. First, how can we understand the relations between these cultural artifacts and the cognitive development of children? Second, how will the very nature of human cognitive and communicative development itself be affected or modified by social and technological development? The former question has been investigated in a number of studies taking both cultural and historical factors into account (e.g., Greeno & Hall, 1997; Roth & McGinn, 1998; Säljö, 1996). In contrast, the second question of the very nature of the interplay between developmental trajectories of individuals and the introduction of new artifacts/social practices in society has received little attention. In the following, we consider both questions by means of an exploratory case study of the introduction of a certain kind of digital representation to a number of young children (aged between 6 and 11 years) growing up in the digital age. What we attend to is the nature of reasoning they engage in the context of digital representations and how this reasoning is coordinated with the technology at hand.

REPRESENTATIONS AND SCIENTIFIC REASONING

Issues of the relation between children's reasoning, scientific concepts, and visual representations are very general and have been investigated from different theoretical positions. The immediate background of this research, however, can be found in two earlier studies by Schoultz, Säljö, and Wyndhamn (2001) and Ivarsson, Schoultz, and Säljö (2002). The common interest in these two studies was to analyze children's reasoning in the area of elementary astronomy. Both studies were conducted to critically dialogue with the research findings in the tradition of studying "conceptual change" within a cognitivist tradition. In the cognitivist studies, children (from 5 years and up) are typically interviewed about their understandings of the shape of the earth and elementary concepts such as gravity. The results generally show that children have various "mental models" of the earth as flat, hollow, and so on and that they often claim that people can fall off the earth or that they can only live on top of it (Nussbaum, 1979; Nussbaum & Novak, 1976; Vosniadou, 1994; Vosniadou & Brewer, 1992).

As much of the earlier research that we wanted to dialogue with had used the structured interview, in the Piagetian tradition of the *méthode-clinique* (Piaget, 1929) to gather data, this method was largely maintained in our previous studies (Schoultz et al., 2001; Ivarsson et al., 2002), although with some significant modifications. One of these modifications concerned the analytical attitude in relation to the empirical material. Instead of regarding the interview situation as a privileged context in which the mind can be tapped of its conceptual content, the interviews were analyzed as concrete social and discursive encounters. A second modification concerned the resources made available to the participants. The children in these studies were given the possibility to reason about elementary astronomy with the support of well-known artifacts such as a globe (Schoultz et al., 2001) and a map (Ivarsson et al., 2002), respectively. The studies showed how a globe or a map supports the reasoning of even very young children to accomplish rather complicated accounts in which sophisticated knowledge about the shape of the earth and gravity was introduced. Contrary to the earlier research (e.g., Sneider & Pulos, 1983), these two studies contained no reports of children saying that one could fall off the earth, a fact that was attributed to the familiarity with and physical presence of the representational objects. Also, there were no suggestions that the shape of the earth was flat or had any other form. Thus, these artifacts seem to serve as quite efficient prosthetic devices for reasoning if one is interested in studying how children are able to use fairly abstract explanations and approximate scientifically acceptable accounts.

From such culturally established artifacts as globes and maps, this study takes the step to the digital medium and representations of a related but at the same time less familiar kind. In a modern society, children will meet a plethora of visual representations in many walks of life in movies, games, books, toys, and so on. The cognitive socialization needed to handle these new, rich, and dynamic representations must be very different from the one that was valid, say, 50 years ago or so. This is the general issue that underlies the observations we report in what follows. Two specific questions are addressed. First, what happens to children's reasoning when confronted with an unfamiliar and dynamic representation? Second, what discursive strategies and resources will children use in their argumentations? These are, of course, very generic questions, and we only exemplify some aspects of them. To simplify the understanding, we keep to the same context as in the studies just mentioned: children's reasoning about gravity and the shape of the earth.

Before turning to the empirical material, we briefly articulate a theoretical framework suitable for the kind of analysis we present.

PERCEPTION, REPRESENTATION, AND ACTION

A fascinating theory of the nature of visual representation and one that is firmly grounded in an attempt to take human practices as a starting point has been developed by the philosopher Wartofsky (1979). Traditionally, philosophers and psychologists have studied and conceived perception as a biological capacity and as a characteristic of the species. Consequently, even though the contents of perception obviously have varied historically, its structures and modes have been understood as ahistorical and determined by humans' visual system as a biological entity. Wartofsky (1979) sketched an alternative view of perception and knowledge more in general, which he referred to as a "historical epistemology." Wartofsky's general argument is that the forms or modes of perception, their very structures, are historically variant; they change historically in accordance with changes in our social or cultural practices.

Following this line of reasoning, several reinterpretations of human perception are necessary. For example, seeing is understood not primarily as a physiological act but as a social and cultural activity. Furthermore, Wartofsky (1979) argued that "the specific feature of perception as a mode of action is that it is mediated by representation" (p. 189). This notion of mediation is compatible with the one developed in the Vygotskian tradition (Vygotsky, 1978, 1986; Wertsch, 1998). As an interesting contribution and maybe even extension of this tradition, however, we view Wartofsky's (1979) insistence on the idea that "it is by the variation in *modes of representation* [italics added] that perception itself comes to be related to historical changes in other forms of human practice, and in particular, to social and technological practice" (p. 189).

To clarify Wartofsky's (1979) notion of a historical epistemology, such a position can be contrasted with Piaget's (1972) genetic epistemology and his theory of developmental stages. An illustrative example connected to the previous discussion of representations comes from Piaget and Inhelder (1969) in their analyses of how children construct representations of the world through drawings of their own. Through the works of Luquet,[1] Piaget and Inhelder (1969) claimed that "until about eight or nine a child's drawing is essentially realistic in intention, though the subject begins by drawing what he *knows* about a person or an object long before he can draw what he actually *sees*" (p. 64). This stage is referred to as "intellectual realism" in which the drawing depicts the conceptual attributes of the model without concern for the visual perspective of the observer. An illustration of this intellectual realism is that in the drawing of a child; "a face seen in profile will have a second eye because a man has two eyes" (Piaget & Inhelder, 1969, p. 64). At about 8 or 9 years of age, "intellectual realism" is allegedly succeeded by "visual realism," and "the drawing now represents only what is visible from one particular perspective. A profile now has only one eye, etc., as would be seen from the side, and the concealed parts of objects are no longer visibly represented" (Piaget & Inhelder, 1969, p. 65).

It is exactly this kind of theory of visual perception that is called into question by Wartofsky (1979) in his argumentation for a historical epistemology. According to Wartofsky (1979), such argumentation builds on an anomalous, 17th-century mechanist model of perception that is known as geometrical optics:

> What I take to be anomalous here are precisely the mechanist feature of the model which confuses a particular theory of geometrical optics—i.e. a theory of the transmission, reflection and refraction of light, especially through lenses—with a theory of vision, and in particular, with a theory of visual *perception*. (Wartofsky, 1979, p. 192)

This difference between a scientific theory of optics and vision as part of human practices is important in a sociocultural perspective. Wartofsky (1979) further argued that both the theory of geometrical optics and the theory of perspective drawing are recent historical developments, which have now become an integral part of humans' visual understanding, or of our visual "common sense." The visual realism that Piaget and Inhelder (1969) referred to is not a universal realism that the child simply acquires; it is a sociohistorically derived model of representation according to which we view objects. However, by carrying on unaware of the relations between developments in science and changes in common sense and "thereby taking

[1]G. H. Luquet (1927) as cited Piaget and Inhelder (1969).

today's common sense to be the universal and unchanging common sense of the species, such philosophy of perception," according to Wartofsky (1979), "remains blissfully ignorant of its own historical limits, and the historical datedness of its models" (p. 192).

There is no reason to doubt the empirical observations reported by Piaget and Inhelder (1969), but their theory of "stages" fails to acknowledge any historical or cultural dimensions and transformations that impact on how humans perceive the world. It is precisely because of this ignorance, to paraphrase Wartofsky (1979), that Piaget and Inhelder (1969) reported how these stages "attest to a remarkable convergence with the evolution of the spontaneous geometry of the child" (p. 66). The solution to this problem—following Wartofsky (1979) and, we claim, Vygotsky (1986)—is to refer the change from intellectual realism to visual realism to a socioculturally learned mode of representation that came with the introduction of perspective drawing.

According to Wartofsky (1979), the manners in which representations are arranged, the so-called modes of representation, mediate people's perceptions. Thus, in such a conception, seeing is understood as guided by our culturally adopted modes of representation that have emerged over time in the context of various human practices. However, not all modes become canonical (i.e., culturally accepted and dominant). The establishment of what Wartofsky (1979) called "canons of representation" must be understood as a historical act, which involves the adoption and acceptance of certain interpretative rules for what counts as a relevant and accurate representation in the context of a particular medium. A visual representation becomes a "conventionally adopted specification, which looks 'right,' or is a 'proper' representation, by virtue of our acceptance of a certain 'vocabulary of forms' " (Wartofsky, 1979, p. 181). Thus, the theory of perspective drawing cannot be seen as an unequivocal premise for a true visual realism that objectively represents the world. Rather, this theory suggests and endorses a particular "vocabulary," and one that has been made canonical in most parts of the Western world. Yet, and this is important, for the individual, its rules and conventions have to be learned through a process of cognitive socialization.

For the individual, familiarity with relevant canons of visual representation is necessary to perform certain actions and to see certain things. Knowledge is intrinsic to the way humans represent things, and this conceptualization makes Wartofsky's theorizing (1979, 1983) highly relevant for the study of learning in educational settings (and elsewhere). Wartofsky's (1979) argument calls for an awareness of the existence of different canons of representation in various practices and the possible conflicts between them. This position seems even more important to consider in present-day society with an increasing exposure to new media and the new modes of representation that are introduced, for instance, through the use of computers in instructional settings. For, as suggested by Healy and Hoyles (1999) and many others, something interesting has happened to visual representations as they have become integrated with digital technology:

> Images now can be externalized through computer constructions, rendering more explicit previously hidden properties and structures. A visual image can be made open to inspection, an object of reflection, which can serve as a building block in an argument—something more concrete rather than transitory and fleeting. Once constructed on the computer, images are manipulable: They can be debugged, reconstructed, transformed, separated or combined together, following sets of procedures with something like the reproducibility and rigor previously limited to symbolic representation. (Healy & Hoyles, 1999, p. 59)

Healy and Hoyles (1999) further argued that given these developments, the role of visual representations in schools must be explored to reach a better understanding of the potentials of the new media and technologies for teaching and learning. It should also be pointed out that researchers, as well as educators, need to know more about how children relate such pictorial and graphic displays and how they manage to incorporate these into their argumentation when "talking science" (Lemke, 1990). This is the issue we explore.

RESEARCH DESIGN

This work should be seen as exploratory. It connects to the earlier research (Schoultz et al., 2001, Ivarsson et al., 2002) mentioned previously about children's understanding of gravity and the shape of the earth through the interest in studying the tool-dependent nature of human cognition and communication. Our ambition is to compare some features of children's reasoning in the context of multimodal digital representations with their reasoning when supported by other forms of representations. What is in focus in this line of research is the interest in children's familiarity with the canons of representations that such multimodal and dynamic digital resources embody.

Participants and Analysis

Interviews were held in a Swedish school during regular school days. Participation was voluntary, and in all, 19 children took part. However, in this analysis, excerpts from four children are included, and we use these as exemplars illustrating variations in children's reasoning. These children were aged 6 (preschool) to 11 (fifth grade). The interviews were carried out in the same manner as in the case of the studies by Schoultz et al. (2001) and

Ivarsson et al. (2002). The purpose was not to find out what the children knew in any general sense. Rather, the idea was to explore the interrelation between their reasoning and the use of some multimodal representations. The interview sessions started with a brief, introductory discussion during which a digital, three-dimensional atlas was used. The children were asked about the meaning of the different colors and whether they recognized any countries. As about half of the children were immigrants, mostly from the Middle East, these discussions often involved the location of a specific country and how one would travel to get there. Other children talked about holiday travels or relatives living on a different continent. After these initial discussions, the interviewer (Jonas Ivarsson) changed to a program specifically designed for this study. The sessions lasted between 10 and 20 min and were audio recorded. All recordings were later transcribed in full.

The Graphical Representation

As a basis for the main part of the interviews, a specially designed program had been constructed using Macromedia Director (Director, 1998). The program mainly consisted of a large picture of the earth, which was a composite of many satellite images without clouds. There was no geopolitical information (see Fig. 8.1). This image was a two-dimensional version of the atlas initially used in the interviews. On the left side of the screen there was also a panel containing various icons. With the help of these icons, different objects could be placed on the earth: a boy, a girl, an airplane, and a rocket ship. These two-dimensional figures could be moved with the mouse, and they had been assigned different behaviors with reference to how they should orient.

The issue that was scrutinized in this study concerns the children's reasoning in the context of the movements of the object representing an air-

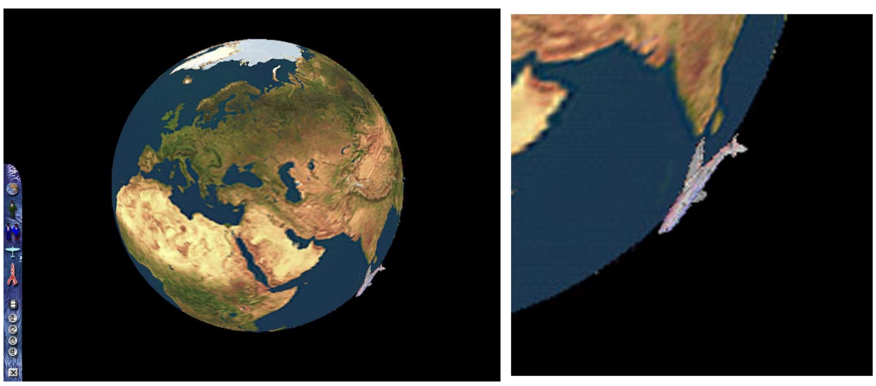

FIG. 8.1. The constructed program with the discussed airplane.

plane. This object had been selected because it was believed that it would prove a more challenging topic when discussing gravity and the shape of the earth than that of people living on different parts of the earth. The plane was always oriented with its underside toward the center of the screen, thus representing gravity. In the interviews, the interviewer controlled the computer program. The plane was first located in the Northern hemisphere and later moved towards the Far East and India. The figure was kept close to the edge of the earth, and the children were asked if it would be possible to travel in the manner suggested by the representation (see enlargement in Fig. 8.1).

RESULTS

The general impression from the analysis of the interviews is the increasing difficulties the children had when reasoning about gravity and the shape of the earth in this context in comparison to what was found in the two earlier studies (Schoultz et al., 2001; Ivarsson et al., 2002) using a globe and a map, respectively. For instance, when the interviews were based on such familiar artifacts, no single child accepted the claim that it would be possible to fall off the earth. Instead, these artifacts seemed to function as cognitive prostheses, making even young children able to participate in complicated discussions about gravity, as we have already mentioned. In this study, however, the representational technology did not function in this transparent manner for the children. Even though this program could be described as more powerful than a traditional, static artifact such as the globe and the map in the sense that it incorporates and visualizes information dynamically, several children had trouble coordinating what they saw with what they already knew. To illustrate this point, we focus the analysis on one particular issue: how the orientation of the plane on the screen should be understood.

In the following sections, we show how the children picked out certain visual characteristics as significant for their reasoning. More specifically, we illustrate how the term *upside down* was used to signal something problematic with this particular representation. We selected four excerpts to illustrate three different ways of reasoning. This grouping is an analytical construction based on the manners in which the graphical representation was incorporated into the argumentation. Our point is to illustrate the kinds of difficulties children had in identifying the modes of representation that are relevant for this particular artifact.

In the first excerpt,[2] Eric, who is about 6 years of age, reasons about airplanes and whether they can travel upside down or not (see Table 8.1).

[2] The transcriptions were made in accordance with Sacks, Schegloff, and Jefferson (1974).

In this interview, as in some others, the fact that the sky is not represented in the computer program constitutes a problem. Eric knows that planes travel in the sky and not in space. He makes a remark about this, and in lines 115 to 118 (Table 8.1), the sky is negotiated. Having established this common point of departure, the interviewer then restates his question somewhat more specifically: "what about here, then? Could one go like this?" Eric's response is a prompt "N:o" with an added justification that the "plane falls down on the ground." This pattern, consisting of a short answer to the question plus a justifying account, is very common in the interviews. It is interesting to note that even at his young age, Eric knows that one can be held accountable for one's claims, and that one therefore has to supply a contextually relevant explanation to the claim made. On a more general level, this illustrates that Eric is familiar with one of the most elementary elements of scientific reasoning. Eric's argument that "the plane falls down on the ground" is open to interpretation, and the interviewer tries to clarify through a suggestion that the plane would fall "down into the water." Simultaneously, the interviewer (in line 121) moves the figure of the plane up on the screen and toward the Indian Ocean. This act can be seen as a form of guidance or offer to render Eric's answer a scientifically acceptable one. Eric does not acknowledge this alternative interpretation and tries to clarify his position by saying that if the plane were upside down, then it would fall "straight down." Here again he introduces an argumentative resource by using the *if-then* structure. After that, the interviewer asks "What's down there, then?," and Eric's response (line 130) implies that it would fall to the "ground."

In this brief exchange, Eric makes two important qualifications in the context of this particular representation. He first introduces the missing sky, and later he adds ground to the scene. Taken together with the plane, these three symbols constitute one of the most common ways of portraying an airplane: as flying in the sky high above the ground. In this sense, one could say that Eric is trying to reconcile what he sees with what he knows about how to represent flying airplanes. Or, alternatively, his argumentation can be interpreted as an attempt to re-create the canon of representation (Wartofsky, 1979) that he is familiar with. This manner of representing, however, is challenged by the images presented by the computer program. Eric accounts for what he sees on the screen as a plane flying "upside down." Thus, the rotation of the represented plane is not taken as something that is relative to the surface of the depicted globe (which would be the expected interpretation if one considers gravity); it is taken as a plane flying upside down.

In the second excerpt (see Table 8.2), Isaac confirms the interviewer's suggestion that it is possible to fly around the globe. Nevertheless, he objects to the way this is represented by the computer program.

In this discussion, the notion of the plane being upside down is again introduced by the child. Isaac is clear about the fact that planes can travel all

TABLE 8.1
Excerpt 1: Eric (Preschool)

111	I:	Does it look like this if we fly here ((moves the plane clockwise, starting from the Northern Hemisphere)) do you think?
112	Eric:	(1.1) No:
113	I:	Round like this-
114	Eric:	Then- then you are- then you see the sky, you don't see the sky when you are up in space=
115	I:	=Oh no so you have to travel about here ((moves the plane closer to the edge)) perhaps
116	Eric:	M:
117	I:	Ye:s (1.2) at the edge like that
118	Eric:	M:
119	I:	Y:es (4.1) but what about here, then? Could one go like this? ((seemingly flying upside down, see Fig. 8.1))
120	Eric:	N:o 'cos then- 'cos then the plane falls down on the ground=
121	I:	= >Do you think it falls down here< down into the water or? ((moves the plane in a northerly direction, toward the Indian Ocean))
122	Eric:	(0.6) No
123	I:	Or where would it go then?=
124	Eric:	=Well if it would have flown in wate:↑r
125	I:	Yes
126	Eric:	And it would've been upside-do:wn it would've fallen straight down
127	I:	Aha (0.4) down here ((moves the plane to the bottom of the screen))
128	Eric:	M:
129	I:	What's down there then?
130	Eric:	(1.5) Grou:nd!
131	I:	Is there ground there?
132	Eric:	M:

TABLE 8.2
Excerpt 2: Isaac (Fifth Grade)

73	I:	Can one fly around the whole earth
74	Isaac:	Yes=
75	I:	Would it be possible to fly like this ((moves the plane clockwise, starting from the Northern Hemisphere and ending up like Fig. 8.1))
76	Isaac:	M: (0.5) but you don't fly upside-down but you can fly around the earth
77	I:	Yes (2.4) but if- if it is like this (0.4) does it fly upside-down then=
78	Isaac:	=>No:<
79	I:	(1.6) But the way it is in the picture then?
80	Isaac:	(1.4) There it flies upside-down but I don't think that it would do that for real
81	I:	No (8.5) if we go like this ((following the curvature of the globe))
81	Isaac:	M:
83	I:	Does it start to tu↑rn then do you think
84	Isaac:	(2.1) °No I don't think so°
85	I:	(1.4) Isn't it possible that the plane fo↑llows the earth
86	Isaac:	(2.2) >I don't know< I've never travelled in a plane myself so
87	I:	No:↓ no then it's a bit hard to know (3.1) but do you think that it could fall off here?
88	Isaac:	No I don't

over the earth, but what he sees on the screen with the plane appearing upside down puzzles him (Table 8.2, line 76). This excerpt illustrates a conflict between what is known and what is seen, a condition that Isaac is able to express very eloquently himself by saying "there [in the picture] it flies upside-down but I don't think that it would do that for real" (line 80). Although Isaac is struggling with how to interpret the picture, the interviewer never really invites him to talk about the premises for the representation in this case. Instead, the interviewer keeps the representation of the plane as the topical focus, and from within such a frame of reference, it is hard to resolve the conflict.

A very similar kind of argumentation is found in the discussion with Helen in Table 8.3. The main difference, in comparison with the previous excerpt, is that Helen manages to explicitly express some of the logic of the representation.

Like Eric and Isaac, Helen spontaneously introduces the term upside down and signals her reactions to the image by saying "you can't fly upside-down." As is the case with Isaac in Excerpt 2, she obviously has problems connecting what she knows with what she sees on the screen. When the interviewer picks up on her remark, she argues against the claim that the plane really is upside down and says that she thinks that it is not. Next, the interviewer shifts the focus from the represented to the representation itself by explicitly referring to appearance: "why does it look like this, then?" This change of topical focus from the represented to the representation seems to be enough for Helen to come up with the answer that the appearance is due

TABLE 8.3
Excerpt 3: Helen (Second Grade)

103	I:	If one travels in a plane like this (0.6) around the earth (2.6) would it be possible to fly here then? ((see Fig. 8.1))
104	Helen:	(3.1) You can't fly upside-down
105	I:	(1.0) No: can you go upside-down or does it go upside-down when it's going like this?
106	Helen:	(1.5) No:
107	I:	(1.0) So it doesn't?
108	Helen:	(1.0) I don't think so
109	I:	No: (0.9) why does it look like this then?
110	Helen:	(1.4) Only because (0.8) it's rou:nd
111	I:	Yes that's right (0.7) so it only looks this way perhaps=
112	Helen:	=Yes
113	I:	(0.5) Yes
114	Helen:	But perhaps it really flies straight=
115	I:	=It actually travels straight yes that's right (2.1) so then it couldn't fall off like this ((moves the plane away from the earth))
116	Helen:	No

to the curvature of the earth: "only because it's round." She then further resolves the conflict by stating that "perhaps it really flies straight."

A third kind of argumentation can be found in the fourth and final excerpt (see Table 8.4). There, the representation enters the discussion somewhat differently in comparison with the other examples in the sense that it does not appear as problematic to the child. This time, the term upside down is introduced by the interviewer as an attempt to challenge the reasoning of the child.

Compared to the earlier excerpts, Oscar has very few objections to the images presented to him. Even though the underlying rationale for the questions is the supposed problems with gravity, Oscar does not seem to share these pre-

TABLE 8.4
Excerpt 4: Oscar (Fourth Grade)

40	I:	Can one travel with aeroplanes all over (0.2) the earth?
41	Oscar:	>Yes<
42	I:	(1.9) Would it be possible to go like this then? ((moves the plane clockwise, starting from the Northern Hemisphere))
43	Oscar:	Ye:s
44	I:	(2.7) How about here (0.7) what happens then? (0.8) ((as in Fig. 8.1)) would it be like this?=
45	Oscar:	=He's flying over the water
46	I:	Flying over the water (1.7) are you supposed to fly like this (0.4) when you are in (1.0) southern Africa?
47	Oscar:	(2.5) Yes
48	I:	(2.5) One isn't upside-down there then?
49	Oscar:	(1.2) Upside-down? (1.2) No: I can't see that
50	I:	(3.5) You only fly like this (4.5) ((completes a full circle and starts on a second lap)) but if I come here (0.2) again ((as in Fig. 8.1)) (1.2) you wouldn't fall here then?
51	Oscar:	(0.2) No
52	I:	(1.7) Why wouldn't you do that
53	Oscar:	Because eh: (1.6) we:ll as I said before, that they think that the earth is flat so you can't- "we will fall down"- they thought a long time ago

mises. Oscar still tries to make the questions as meaningful as he can. In line 44 (Table 8.4), he gets the rather vague question "how about here, what happens then?" This is very close to a leading question because it suggests that something should happen when the plane is in that particular position. Oscar responds by saying that the plane is "flying over the water" (line 45), and through this, he denies that there is anything remarkable in the picture. Oscar responds to the next question (line 46) with a hesitant "yes." Realizing that Oscar handles the representation seemingly without problems, the interviewer then changes tactics in his questioning. The interviewer's next question—"one isn't upside-down there, then?"—is much more straightforward and focuses on the represented phenomenon as he uses the indefinite pronoun *one* together with the adverb *there.* Oscar opposes the implied proposition, and the particular manner in which he does this is very interesting. At first, he seems baffled, as he repeats the word "Upside-down" with a questioning intonation, but then he adds, "no I can't see that." Oscar's wording, in our opinion, is quite revealing: "Upside-down? No I can't see that." Oscar's problem with this question seems to be that he cannot understand why it is asked in this particular manner. Because the interview implies an asymmetrical power relation set within the school context, Oscar is obligated to take the questions as relevant and not arbitrary. By introducing his own perspective in the answer, Oscar simultaneously denies that the plane would be upside down and implies that there may be other interpretations as well (e.g., the perspective implicated by the interviewer and that he cannot identify).

An important element of the utterance in line 49 (Table 8.4) is the use of the word *see.* In Swedish, the word (*se*) does not share the same close connotations of "knowing" or "understanding" as does the English term and in this situation; it should be interpreted in the literal, that is, visual sense of the word. In the two earlier excerpts, the children's previous knowledge came into conflict with their reading of the visual representation. They obviously saw something—a plane seemingly upside down—which they initially found somewhat confusing. In contrast, Oscar says he "can't see" how the plane could be upside down. It is tempting to explain this difference by saying that Oscar has a better theoretical grasp of phenomena that relate to gravity. However, such an explanation risks being circular and begs the question of exactly why Oscar does not see the plane as being upside down. In the following section, our discussion focuses specifically on these differences in reasoning and their relation to culturally adopted modes of representation.

DISCUSSION

If a representation, as suggested by Wartofsky (1979), is seen as a form of specification, then a certain set of adopted rules may be regarded as intrinsic to any representation—but only as long as one remembers that "representing is something that we *do*, and that nothing *is* a representation excerpt insofar as we construct or construe it as one" (p. xxi). Thus, it is important to keep in mind that any representation may refer to several practices, and the relevant interpretations of a representation between these may differ. This line of reasoning becomes clearer if illustrated by the case of the earth and its various representations.

When the earth is talked about as an astronomical body, which is one of the many ways we as humans can discuss our planet, a number of details are made relevant: the spherical shape, certain rules of gravity, and the somewhat strange fact that this massive body seems to "float freely" in space. If the particular representation of a globe is used in such an astronomical discussion, the spherical shape is physically present and does not have to be added. The concept of gravity, however, is not directly represented by the globe, and to explain various observations (such as that airplanes will not fall off the globe), the concept will have to be invoked or at least recognized by the speakers as a relevant premise. If, instead, the very same globe is used in a history class while discussing the journeys of Columbus or the first attempts to sail around the globe, gravity will most likely not be an issue at all. In this case, the spherical shape of the earth, the location of different continents, and the navigational problems of finding passages will probably appear as the relevant features to focus on. Thus, the globe affords a range of different perspectives and discursive practices that focus on different features.

When representations are embodied in a digital medium, the possibilities of incorporating conceptual distinctions increase significantly. Things that cannot be represented on a flat sheet of paper or through a mechanical construction can come alive in several modalities simultaneously, for instance, through visual, aural, tactile, and proprioceptive[3] displays or any combination of these (Biocca & Delaney, 1995). The representation used in this study differed from a globe in several respects. It was a two-dimensional image presented on a flat screen, but it was also interactively fixed (because it was a projection from a single viewpoint). On the other hand, it did model events on the basis of the concept of gravity through the dynamic orientation of movable objects. This whole configuration embodies a mode of representation that turned out to be quite challenging for some of the children who had to struggle with what they saw. Previously, we have shown three analytically distinctive forms of reasoning that are illustrated in the four excerpts. We argue that these differences in reasoning are related to differences in perception of the graphical representation. We recapitulate some of the observations and add some theoretical interpretations.

[3]The human proprioceptive system registers the motion and position of both individual limbs and the body as a whole. The most easily recognized proprioceptive display would probably be the roller coaster or other forms of theme park attractions.

In the first case, Eric brought in what he saw as the missing elements of the image, that is, "sky" and "ground," to arrive at a picture of a plane over which he had some conceptual control. Through his reasoning, he actively construed a mode of representation that was not physically present, a mode illustrated by Fig. 8.2[4] (which is a drawing by a child taken from a different context). If one considers the manner in which Eric considers these added elements necessary for illustrating how airplanes fly, the isolated airplane presented on the screen (see Fig. 8.1) could be understood as upside down.

One important thing to realize in this context is that Eric was working very hard to make the discussion intelligible, in part by adding thematically relevant elements that had not been mentioned by the interviewer. Furthermore, it should be noted that it was not only the interviewer who contributed with modes of reasoning that were theoretical in character. Eric's seeing was also theoretically informed, although by an alternative mode of representation. Eric displayed skills in reasoning, indicative of familiarity with a particular kind of scientific argumentation, through the use of an *if–then* structure and by realizing that he would be held accountable for his claims. What Eric did not seem able to do—at least not in this discussion—was to go beyond his adopted frame of reference and realize some critical features of how this particular representation was designed. Unlike the inter-

FIG. 8.2. Child's drawing of planes.

[4]Note that this illustration is taken from a different context. The drawing was done by Daniel Meyers, Grade 6, and can be found at http://quest.arc.nasa.gov/aero/events/regimes/contest/Daniel-Mun-SS.jpeg

viewer, Eric was not simultaneously managing different canons of representation; however, we do not discuss this further here.

Turning to the talk with Isaac and Helen (Excerpts 2 and 3), these discussions differed from Eric's line of reasoning mainly because they focused on a conflict between what they saw and what they knew. To Piaget (Piaget & Inhelder, 1969), these excerpts would represent an intermediary or perhaps unaccounted for stage between intellectual realism and visual realism. However, by following the argumentation of Wartofsky (1979), it seems reasonable to assume that Isaac and Helen struggled with two alternative and radically different canons of representation at the same time. Both children noted and commented with some surprise on the fact that the plane appeared upside down. By further considering and discussing how airplanes fly, they were able to bracket their initial, visual interpretation of an airplane apparently flying upside down and reinterpret this appearance in line with a mode of representation premised on gravity. To take the next step of explicitly formulating this, however, both children seemed to need some mild communicative support, and as it turned out, only the discussion with Helen resulted in an explicit verbal resolution of the conflict between what was seen and what was known. Helen's coming to this conclusion must be construed as an interactive achievement, and it illustrates how reasoning with the support of others may take people further in their understanding of a given representation.

The practice of representing objects as following the spherical earth is a relatively recent one. It is also less frequent than the canon of linear perspectivity discussed earlier. Nevertheless, Oscar (Excerpt 4), representing the third way of reasoning, displayed a familiarity with this new representation, the same mode of representation that Eric never really dealt with and that Isaac and Helen had only started to apprehend. Compared with the three other children, Oscar had the inverse problem when talking about the orientation of the plane. To him, upside down did not seem a fitting description of what the image portrayed. On the contrary, he seemed so attuned to the mode of representation where gravity is visualized in a particular manner that he did not see how the plane could be described as upside down. Most likely, even Oscar could be instructed to see the plane as upside down, but he did not seem to consider this relevant in a discussion premised on the notion of gravity and the movement of objects around the earth.

On a general level, the development of reasoning and human knowing schematically visible in the four excerpts can be understood as related to the constant adjustment of human perception to evolving technologies. When human knowledge is transformed and given a material shape through externalizations in the shape of various symbolic representations, such resources will serve as active elements in the cognitive socialization of future generations of learners. Through this duality inherent to material objects embodying specific conceptual structurings, the insights and perspectives that have emerged through sociocultural evolution will live on in society. Thus, objects are not simply out there in the world. Rather, they are instructive and actively contribute to sustaining specific manners of reasoning and perceiving. In some cases, they will even be naturalized and assumed to perfectly match what they represent in a mirror-like fashion. However, the important point to keep in mind is that our modes of knowing are continuously transformed as technologies contribute to the reconfiguration of our practices.

CONCLUSION

The overall aim of this study was to explore some of the relations between representational technologies, perception, cognition, and human action. The evolution of digital technology has opened up new possibilities for visual expression, and when these representations enter the classroom, pupils will face the problem of coming to grips with the conceptual premises of these representational tools. The question is how children disambiguate and manage to make productive use of such tools for understanding in the learning environment.

The point of our study was to contribute to a better understanding of the potentials of the new technology for teaching and learning. To address this issue, an unfamiliar and dynamic representation was introduced to a group of young pupils. The analysis focused on the scientific reasoning that took place in the context of such an artifact and what discursive strategies and resources the children used in their argumentations. By grounding our analysis in the theoretical position suggested by Wartofsky (1979), we have attempted to illustrate how the pupils, to grasp the graphical environment, made use of distinctions and perspectives that are indicative of specific canons of representation. The results suggest that perception and understanding are closely interlinked with these cultural modes of action. Furthermore, it is through the successive adoption of these modes that cognitive development itself becomes related to social and technological change.

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