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Kids in Zen: computer-supported learning environments and illusory intersubjectivity

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SAMMANFATTNING *Med introduktionen av nya tekniker förändras samtidigt villkoren för det mänskliga lärandet. Digitala medier, med interaktiva och visuellt baserade lärandemiljöer, utmanar de traditionellt språkligt baserade kommunikationssätten. Detta är åtminstone vad som påstås. Studien undersöker en kort sekvens där en grupp elever, tillsammans med två lärare, undersöker en komplex uppgift som handlar om rekursion i relation till programmering. Resultaten antyder att den begreppsliga kunskap som eleverna utvecklar är knuten till den konkreta situationen. Den visuellt rika miljön stöttar eleverna i deras arbete med uppgiften, men det finns inget som tyder på att några relevanta begreppsliga distinktioner lärs på det sätt som var avsett.*

ABSTRACT *The nature of human learning changes as new technologies are introduced. Digital media, with interactive and visually driven learning environments, challenge the traditional, linguistically dominated, mode of communication. At least, this is what is claimed. The study explores a short sequence where a group of students interact with two teachers in the context of a complex learning task dealing with recursion in relation to programming. The results suggest that the mastery of conceptual knowledge that the students develop is tied to local features of the situation that they operate in. The rich environment provides a number of cues that assist the students in handling the task, but there is no indication that the relevant conceptual distinctions are mastered in the manner intended.*

Introduction

> *Zen teaches nothing; it merely enables us to wake up and become aware. It does not teach, it points.* (Daisetz Suzuki)

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In the introductory quote, Daisetz Suzuki, the chief emissary of Zen to the west, articulates a distinction between *teaching* and *pointing*. Although this distinction might not be valid as a general principle, it serves a purpose in this particular context. It applies to the following work in that it makes us aware of the fact that we are able to accomplish many things only by pointing, without conceptualising the object that is being pointed at. This non-conceptualisation is very fundamental to some practitioners of Zen. In fact, the prominent method of Rinzai Zen is to provide each student with something called a *koan*. The koan is a form of riddle, often built on a paradox, whose function is to short-circuit the intellectual and conceptual system of the student. This rational *cul-de-sac* is considered the true starting point in the study of Zen (Suzuki, 1991).

This should be contrasted with schooling practices which aim to deepen and expand the student's conceptual understanding of the world. Such practices are well established and can be seen as the current norm. For instance, the curriculum for the Swedish compulsory school states that all students should come to know and understand basic concepts and contexts within the natural sciences as well as within technical, social and humanistic areas of knowledge. Tools of various kinds have always been involved in this process, but today information technology has seriously entered the stage as a rather new actor.

Information technology has, as it were, already been incorporated into school practice by large government subsidies. Many now ask the question whether the millions of Euros spent contribute to better learning. Some educational researchers seek the answer to this question by analysing the *technology* (e.g. Jonassen, 2000; Allinson *et al.*, 2001), others try to explore what *modes of cooperation* best promote learning with computers (e.g. Bielaczyc, 2001; Lahti *et al.*, 2001). Instead of contributing directly to the perpetual debate on what learning really is, or surveying the affordances of a specific technology, this work aims at investigating the intricate relationship between learning and technologies, not forgetting the historical dimension of what one *has to* learn.

What people have to learn is never constant but changes over the course of time. It is often associated with the development of new technologies. But new technologies are not the sole determinant of how people come to act. For example, the practice of navigation has changed its methods many times throughout the centuries and thus repeatedly made new demands on succeeding generations of navigators. In the late fifteenth century, the method of navigating with the aid of the quadrant, stars and latitudes developed. Although more efficient than the previous practice of sailing in a circle (the so-called *volta*), these new tools did not themselves guarantee their successful use. 'The new method of navigation proved difficult for most mariners. Only the most up-to-date sailors attempted its practice, and there is evidence that Columbus, among others, understood it only imperfectly' (Law, 1987, p. 126). In order to make the instruments, the inscriptions (latitudes), and the stars effective parts of the practice of navigation, a new social group had to be established. Such a group emerged, in Lisbon in the early sixteenth century, through the *teaching* of astronomical navigation to pilots (Law, 1987). In a similar fashion, one could suspect that the educational potentials of information technology have to be materialised through the founding of specific educational practices.

During the twentieth century, the pace of technological changes accelerated in a way unparalleled in the history of humankind. This trend continues and it constitutes a great challenge to learners of today. Today, we demand more from our young children than the seafaring nations in the fifteenth century could possibly have demanded from their already skilled navigators. Related to the domain of education, modern information technology has thus become an issue of immediate interest to examine. This is so, not only because it is associated with large financial investments, but also because it represents a significant feature of sociocultural development.

Studying Learning with Computers

From the perspective of the theoretical tradition guiding this work, learning is always, to some extent, unpredictable. Learning is seen as dependent on interpretation and not as the straightforward acquisition of facts. The indeterminacy associated with the act of interpretation actually holds a potential for new development. If learning were the mere copying of old forms of knowing, development would come to a halt. But what happens to the scope of interpretation with the introduction of such means as digital media? One interesting feature of interactive computer-based learning environments is that they afford a number of actions beyond the purely linguistic. Besides describing, for example, physical phenomena, the student can manipulate and influence the processes in progress. The expectation is that activities of this kind will provide instant feedback and, hence, make learning less abstract. In some cases, the digital environments also come enlarged with physical peripherals. Taken together, such environments constitute rich fields of potential actions of various kinds. As a consequence, what students do, and learn, in these environments may vary to a large extent.

The theoretical background to the present study is the large number of studies addressing the area of computer-supported collaborative learning, from a sociocultural and/or situated perspective, that has emerged during the last decade. These studies has tackled issues like: gender and information technology (Kafai, 1996; Light & Littleton, 1997; Littleton & Bannert, 1999); different educational potentials of the new technology (Hennessy & O'Shea, 1993; Roschelle & Pea, 2002); how computers can support collective thinking and knowledge-building (Mercer, 2000; Scardamalia & Bereiter, 1994; Säljö, 1999), etc. Common for most of these studies is the principal interest in communication. Language is seen as the primary means for cognitive development and it is argued that it must be analysed accordingly.

In analyses of collaboration in interactive learning environments, the concepts of ZPD (Zone of Proximal Development) (Vygotsky, 1978), scaffolding (Bruner, 1985) and affordances (Gibson, 1979) are frequently utilised. However useful as general ideas, they lack the acute sensitivity to the communicative events that is sometimes needed. In an attempt to unravel some of the complex interrelationships between students and technology, the present study will adopt additional resources from thinkers deeply concerned with 'language in use.' Building on the theoretical position set out by the later Wittgenstein and followers like Rommetveit, the analysis will make use of methods from ethnomethodology (Garfinkel, 1984) and interaction analysis (Jordan & Henderson, 1995). These kind of video-based studies of technologies and social interaction are, so far, most often found in workplace studies in the field called computer-supported cooperative work (CSCW). This approach is driven by a number of analytic concerns and assumptions, helpful in the investigation of how people use technologies. Part of this methodology is the treatment of 'talk, bodily conduct, the use of tools, technologies and the like, as ways in and through which participants accomplish actions and activities; actions and activities which rely upon, and embody, social organisation' (Heath & Luff, 2000, p. 23). There is also a concern for the resources in and through which participants themselves produce their own actions and recognise the actions of others.

Learning Context and the Aim of the Study

The technology used in this study—LEGO-dacta—is an example of an interactive computer-based learning environment. The product originates from collaboration between the company LEGO and researchers at MIT Media Lab. The rhetoric accompanying this kind of product is extensive and mixes results from research and visions of the future with more or less well-founded sales arguments. According to the Swedish retailer, LEGO-dacta is supposed to function together with problem-based learning. The students are supposed to acquire knowledge by adopting an experimenting way of working. Furthermore, it is claimed that the software (TechnoLogica) 'gives an understanding of the foundations of computer science, such as structured programming, recursion (reiteration), open and closed loops in programming' (Elevdata, 1999, my translation). When studying learning and the use of computers, however, one must remain neutral to assertions of this kind. What students actually do when they have access to these computer-based environments is an open question.

The aim of this study is to give a contribution to the larger, general discussion on learning and technologies, with observations of local and specific practices as its point of departure. For this work, a detailed description of a single case will be used. The case is a short sequence in which three students, together with two supervisors and supported by technology, reason about one of the fundamental principles of computer science. This sequence comes from an extensive body of empirical material (see below), and the selection is made with the purpose of giving a concrete example of a discussion on a complicated matter. The interest concerns what students do when they are working in this environment, what the nature of the communication is and what resources the participants utilise in their interaction.

Empirical Study

The material presented here derives from a study where 32 pupils in the sixth grade[1] had the opportunity to work with the equipment called LEGO-dacta during a period of 2 weeks. The class was divided into 10 groups, who worked with the technology on three separate occasions. The sessions lasted for about 30 to 60 minutes and took place during regular school hours. To help them, the students had two researchers (Jonas and Patrik), who functioned as teachers. The main part of the sessions was recorded with two video cameras plus a video cassette recorder capturing the computer screen.

The results presented here are based on an analysis of a *single case*, a short sequence where three students are introduced to a new problem—recursion. In relation to the students' current level of education, the complexity of the problem is very high, something that makes this sequence all the more interesting to examine. Normally, this problem is first introduced at a university level; nevertheless, it seems as if the students quickly grasp the nature of the problem and try to contribute to its solution. From an educational perspective, this is fascinating. How is it that these young students suddenly manage to reason about such sophisticated logical issues? It is surmised that the technical environment is used as an important resource and the analysis aims to thoroughly scrutinise the course of events in order to elucidate the different roles played by the participants and the technology. But before we can do this, the reader must be acquainted with both the technical equipment and the problem the students face.

The Technical Environment

The LEGO-dacta technology is a further development of LEGO Technic, which can be controlled by electrical motors. Accompanying the building bricks and motors is a range of input and output devices such as light sensors, pressure sensors, thermometers, angle sensors, lamps and loud-

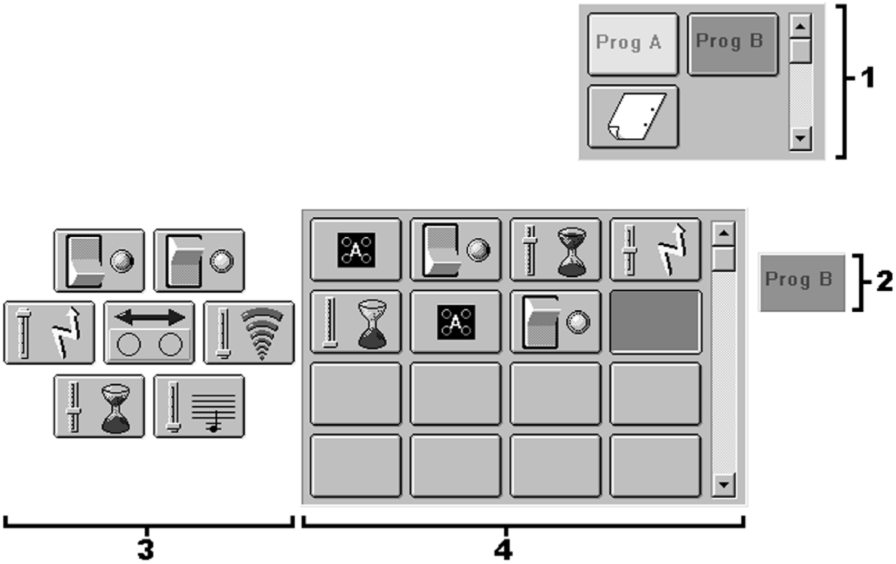

FIG. 1. Utilised parts in TechnoLogica.

speakers. The peripheral equipment is connected to an ordinary PC by a set of cables. To control the interaction between the mechanical parts, a graphical icon-based programming language is used (TechnoLogica, see Fig. 1).

In TechnoLogica, the user can create small *functions*[2] (1 in Fig. 1). Every function is made up of two parts, its *name* (2 in Fig. 1) as well as its *content* (4 in Fig. 1). The content is arranged in the form of a list and normally contains a number of *instructions* (3 in Fig. 1).

Simply dragging and dropping instructions onto their desired position constitutes the actual programming procedure. When the user is finished, the function can be executed, and, when this is done, the computer reads through the list of contents from left to right, like a text.

Recursion as Problem

In the example analysed in this study, three students in the sixth grade are reasoning about a problem that could be characterised as being about recursion. If one looks up the word recursion in a dictionary one might come upon such explanations as: 'To define something in terms of itself' or, in more laconic wording, '***Recursion***; see recursion.' These definitions, however, are not very informative, especially not when it comes to such issues as how the concept is used in practice. One way to give an initial description is to use a visual metaphor. Fig. 2 can be described as a visual recursion. The picture contains, as an element, a copy of itself—or somewhat differently expressed—a reference to itself. This miniature picture itself contains a smaller copy, and so on. Accordingly, this results

FIG. 2. Pictures in pictures.

in several different levels of pictures. Since the visual recursion is dependent upon the resolution of the picture, there is a finite number of levels. In principle, though, there is no need for any further limit to repetitions, the recursion could go on forever.

Recursive pictures are not entirely uncommon and occur in various contexts. Recursion as a phenomenon in mathematics and computer science, on the other hand, is something that most people normally never come into contact with. One reason for this is probably that the first introduction of the problem normally occurs at university level. It is interesting to note that this introduction of the concept, for example, in courses on programming, is sometimes considered to be a critical stage, requiring much time and energy. In spite of this, many textbooks still rely on formalised language in their explanations. Here is an example from a manual for (LISP) programming.

> *By* recursion *we mean an algorithm that in its definition refers to itself. A* recursive function *is a function that in its definition makes a call to itself, either directly or indirectly via other functions. [… .] Every recursive function must have a terminating condition. Normally, it is one of the formal parameters that in some way is counted as matching the terminating condition. If this were not the case, we would have an* infinite *or* interminable *computation.* (Haraldsson, 1993, p. 36, my translation)

In this quote, the author warns against the *infinite recursion*. By and large, this is the same thing as the repetition depicted in Fig. 2. In a picture, this is not a problem, but if one wants to write a functioning program, however, the computation cannot go on forever. From a methodical point of view,

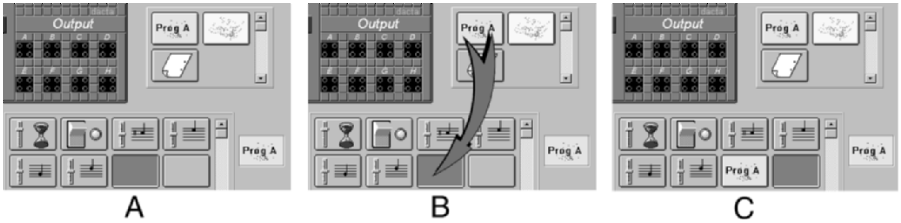

FIG. 3. Modification of the function.

recursion is portrayed as a natural way of describing and defining many problems (Haraldsson, 1993), and it can also be applied to other domains (e.g. biology) (Bateson, 1979).

The Local Design of the Problem

The aim of the activity studied was to *introduce* and *discuss* some problems associated with functions that refer to themselves. To facilitate the reading of the interaction that took place, the local design of the problem will first be introduced.

During the first part of the session, the students had created a short function (here called ‘Prog A’). Fig. 3–A illustrates the end of this function with six visible instructions. When the function is executed, the instructions are carried out from left to right, one row at a time, and then come to a stop. Creating functions in this manner, with one main function containing a number of instructions, is the most basic way of using the software and it was also the way the students had been using it. TechnoLogica does, however, like other more advanced programming languages, allow functions to contain other functions.

Not only can a function contain other functions and instructions, it can also contain its own name. If *Prog A* is modified (see Fig. 3–B) to look like Fig. 3–C, we have a more complex algorithm. The function *Prog A* now contains a reference to itself and, accordingly, it becomes a recursive function. When this new function is executed, the computer carries out the instructions in the given order until it reaches the last icon, it then runs the same function from the beginning and so on. Since there is no terminating condition this can be described as an *infinite recursion*. It was this form of self-reference and its associated problems that comprised the topic for the discussion between the students and the teachers.

Findings

The example presented here comes from the latter part of this group’s first session. The group has finished the formal exercise and a negotiation arises concerning what should be done during the rest of the time. Together with the two teachers Jonas and Patrik, the students agree to examine a new and unknown problem, which is then demonstrated by Jonas (see Excerpt 1)[3].

Excerpt 1

1	*JONAS*	*if one were to put* this *program ((points at prog A)) (.) at the end there*
2	*Isaac*	*here*
3	*Michael*	*there*
4	*JONAS*	*there that's right. what do you think will happen then?*

In the formal exercise, the students had created a short function, which is used here as a basis for the new problem. Jonas encourages the students to place the name of the function (Prog A) at the end of its own list of contents ('if one were to put this program at the end there'; cf. Fig. 3). This instruction is expressed in the form of an unfinished question, something that highlights the importance of the manipulation of the function. The question format prepares the students for the fact that this action will be significant in the subsequent task. The students implement the instruction, whereupon Jonas finishes his question ('what do you think will happen then?').

The 'problem,' which is introduced here, rests upon a rich conceptual world and can be understood in relation to specific ideas with a long history in computer science. For the teachers, this is a *concrete example* of recursion as a *general principle*. It is noticeable, however, that this is not how it is described to the students. The communicative resources used in this sequence are first and foremost the layout of the computer screen and the function already constructed, together with pointing gestures and simple words like 'here' and 'this.' There is nothing in the conversation to indicate that this might be an example of any mathematical notion or the like. On the contrary, the problem is presented in common parlance, something that hides any potential connections to other contexts.

Excerpt 2

5	*Michael*	*[well it will run-*
6	*Isaac*	*[it will run once more*
7	*JONAS*	*then it will run once more yes*
8	*PATRIK*	*what happens th- [will it ever stop-*
9	*JONAS*	*[but then it will come to the same place =*
10	*Isaac*	*= where it stopped*
11	*Anna*	*going to go like that*

		[the whole bloody time, then
12	*Michael*	*[going to go round*
13	*JONAS*	*that's right*
14	*Michael*	*Cool*

This excerpt clearly shows how quickly the students can respond to the teacher. The argumentation clearly points to some form of appreciation of the local problem. Jonas' question ('what do you think will happen then?') is immediately followed by simultaneous answers from Michael and Isaac. The teacher confirms these answers but he also problematises them further ('but then it will come to the same place'). Isaac, finishing Jonas' sentence, shows that he is deeply involved. Both Anna and Michael then formulate the consequences of placing the name of the function at the end of its own list of contents. And again, doing this at the same time, they reveal how well coordinated they are in relation to the problem.

The communication articulated by the students very much mirrors the expressions used by the teachers. Their conversation is carried on with words that have a strong connection to the situation. There is, however, an important difference from the (theoretically motivated) argumentation of the teachers. The answers given by the students seem to be motivated by the present situation and their recently acquired knowledge of the technical environment. Unlike the teachers, the students cannot benefit from earlier experience of situations beyond this one. At this point, there arises a question concerning the role of the technology in the interaction. Since all participants have access to the computer screen, this surface can be used as a common point of reference. With such simple means as pointing gestures and words like 'this,' 'there' and 'it,' they can communicate about the immediate surroundings and objects on the computer screen in particular. In view of the fact that the problem is visually illustrated, much of the communicative work is restructured, with its main focus shifting from linguistic descriptions to the technology.

Excerpt 3

15	*Isaac*	*if you take one of those, then ((places the cursor on the icon with an open switch))*
16	*Anna*	*no, °get real°*
17	*JONAS*	*mm would that be possible?*
18	*Isaac*	*no you can no-*
19	*Anna*	*no*
20	*Michael*	*[yees after there*
21	*Isaac*	*[but we c-*
22	*Anna*	*noo*

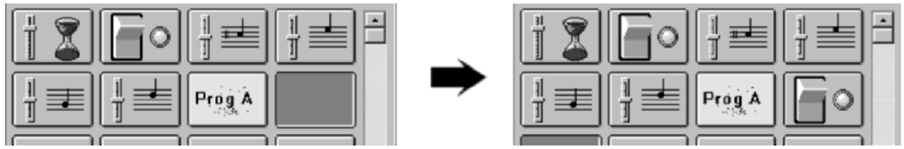

FIG. 4. Proposed alteration of the function.

In this third excerpt, the students try to solve the problem with the looping function by means of local resources. In this manner, they are trying to use once again the building blocks from the technical environment they have just encountered and mastered. This environment and the possibilities it affords provide the basis from which the students now draw resources in order to solve the problem. An example of such a resource is the icon portraying an open switch. The purpose of this instruction is to interrupt the current that is fed to the Lego models. Isaac points at this icon and asks whether it can be of any assistance ('if you take one of those, then'). This initiative is the starting point for a negotiation between the participants and several viewpoints are aired. Isaac later withdraws his proposal, possibly a consequence of the somewhat threatening response he receives from Anna ('no, get real'). An alternative interpretation of this sequence is to describe the students' mode of talking as something Mercer and Wegerif (1999) call 'exploratory talk.' With this expression, they have in mind a way of talking where arguments are launched without the speaker having yet decided on their relevance. It is clear, though, that Michael jumps at this idea and suggests that the instruction be put at the end of the list of contents (cf. Fig. 4).

A possible way of describing technology, and in this case the program TechnoLogica, is in terms of accumulated experiences inscribed in the form of distinctions (Latour & Woolgar, 1986). Some of these distinctions have been shaped like instructions (icons), which in turn are easily accessible to the users. By simply referring to or using some of these icons, the students can utilise the underlying distinctions, without understanding how they operate. When Isaac presents his proposal (in line 15) he uses the phrase 'one of those' together with a circular gesture with the cursor. He does this in order to call attention to the icon with the open switch. The use of this expression is a good example of how much of the communicative work can be transferred to the screen or delegated to the other participants. Isaac does not necessarily need to know what the icon is called or how it operates. Neither does he have to remember what instructions there are in order to come up with this suggestion. Nearly every feasible action in the program TechnoLogica is represented on the screen in the shape of icons. Given this fact, the students can assume that the manipulation of these icons is all that it takes to solve the task in question. None of the students discusses the problem on a more general level or tries to widen the scope of the situation. They are completely engrossed in finding a solution to the problem, given the framing that was established during the first part of the session. This narrow attitude should still be considered reasonable since there have been no indications from the teachers that this activity should or even could be related to other activities.

Excerpt 4

23	*PATRIK*	*will it ever c- will it ever come to the step after that one?*
24	*Isaac*	*mm*
25	*Michael*	*yees*
26	*Isaac*	*[noo*
27	*Michael*	*[noo*
28	*Anna*	*why would it* not *do that?*
29	*PATRIK*	*'cause if you think when it if it goes through the whole program*
30	*Anna*	*Yes*
31	*PATRIK*	*then it will tell it to run the program again, kind of, and then it will enter the program again*

From his earlier experience with recursive functions, Patrik can immediately detect the shortcomings of the newly proposed function. Since the computer works sequentially, doing only one thing at a time, it will always enter a new copy of the function before it can reach the end that Michael had in mind for the switch. Every instruction located after the function's call to itself can be regarded as non-existent. By formulating the question 'will it ever come to the step after that one?,' Patrik problematises the students' solution. His phrasing, however, renders the objection nearly impossible to apprehend as being of a general kind. Instead, it is taken as a critique against the locally suggested function. Just like earlier, the general mathematical principle is mediated by the LEGO-dacta technology and is presented in common or local parlance. Consequently, it is restricted in its range of application.

What happens in lines 24 to 27 is especially interesting. With some hesitation, Michael repeats his earlier view when he responds to Patrik's question. But he soon shifts position and in unison with Isaac exclaims 'noo.' Anna, however, remains doubtful about this change, and her question 'why would it *not* do that?' motivates Patrik to give a more detailed description of what will happen when the function is executed.

How is it that the students so quickly discover the consequences of the newly proposed design? Michael and Isaac seem to need very little help in order to see that the function will never come to a halt. And here, emphasis on the word *see* is needed. The visual and interactive character of the environment gives the students good support for their reasoning. Without this rich visual base, it is unlikely that the students (who are to be considered as beginners) would have come up with such a fast response to the sophisticated question (line 23).

Excerpt 5

32	*Michael*	*then we'll put a*
		[stop
33	*Anna*	*[mm *yees**
34	*PATRIK*	*then it will never reach the*
		[step after that one
35	*Michael*	*[*it can't be done**
36	*Anna*	*[mm*
37	*Michael*	*[oh yes, at the beginning a stop at the very beginning*
38	*Isaac*	*well?*
39	*JONAS*	*what will happen then?*
40	*Anna*	*but then the program will stop*
		[you have to think
41	*Michael*	*[but- he's telling it after there to* start. *if you put it before the A.* like that
42	*PATRIK*	*try it out and see what happens*

In excerpt 5, the students continue the discussion and modify the design. They are trying to place something they call a 'stop' (i.e. the icon with the open switch) in a section of the sequence that they know, from the previous discussion, will execute. Their aim is to stop the *function* from running. This has never been of interest earlier during the session, when all functions ran from beginning to end. As mentioned earlier, the purpose of the instruction is to interrupt the *current* being fed to the Lego models. This is the only way they have been using it and it is also the only way it can be used. The reasoning exhibited here can be described as a trial-and-error attitude and contains nothing qualitatively new. The students fail to discover that this problem has a logic that exceeds that of the other problems they had been working on earlier. Consequently, they continue to work within the framework that was established during the first part of the session.

The attempt to use the instruction ('stop') in this unusual manner could be seen as a manifestation of creativity. An alternative way of looking at the matter is that it is a consequence of the students' lack of conceptual tools. It should be noted that they do not have access to the specific distinction between 'current' and 'function.' Without this distinction, it is hard to realise a priori that the instruction operates only with one of these categories and not the other. Although aware of the shortcomings of the new design, Patrik encourages them to execute their plans, in order to have something new and concrete as a platform for further reasoning.

Excerpt 6

43	*Anna*	*[don't think it will work though*
44	*Isaac*	*[then you have to re- remove this one*
45	*Michael*	*no*
46	*Isaac*	*place this one here*
47	*Anna*	*just* take- *ouch*
48	*Isaac*	*remove*
49	*Anna*	*just take* Isaac
50	*Isaac*	*eh yes. now I should press (.) this one?*
51	*Anna*	*mm*
52	*PATRIK*	*now look at the steps to see what it's doing*
53	*Isaac*	*it's doing it all over again*

In this excerpt, the students make the alterations to the design that Michael had suggested. When they are about to execute the function, Patrik highlights a certain section of the screen ('now look at the steps to see what it's doing'). This window shows exactly what instructions the computer is executing at that moment (i.e. a *debugger* in computer jargon). Isaac then declares that they have failed when he points out that the function has restarted ('it's doing it all over again').

Excerpt 7

54	*JONAS*	*it did stop there but then you turned it on again*
55	*PATRIK*	*what was it- what was it that stopped there. when you added the stop. it just shut off the current there, then. it didn't st- it never stopped the program, right?*
56	*Isaac*	*mm*
57	*Michael*	*no*

Jonas tries to elucidate what happened when they executed the function. He gives a description of the course of events that happened too quickly to be perceived visually. Somewhat indirectly, Patrik then introduces the necessary distinction between current and functions. This is the first occasion where the teachers try to make the session more abstract or conceptually oriented. Irrespective of this change, the discussion ends here, since Anna, having lost interest, successfully introduces a new topic.

Discussion

To begin the discussion, a short recapitulation of the results is needed. In the excerpts analysed, mainly three themes have been salient. The first of these is about how the interactive and visual character of the technical environment affords a specific way of working and talking, a communicative style dominated by demonstrative words and gestures. This kind of communication reflects what researchers call *deixis*[4] (see below). The second theme involves the possible conflict between this (deictic) language and more theoretical knowledge. And, finally, the last theme revolves round how this conflict is concealed from the participants by the wider scope of interpretations provided by the demonstrating expressions. These topics will be examined separately before the discussion is concluded with some general remarks on the role of this technology in science instruction.

Deictic Dominance

When we are using language, we employ expressions that, in order to be interpreted correctly, depend on the context or what has been said before. This dependence is essential when it comes to certain expressions, which linguists call *deictic* (Rommetveit, 1974; Allwood & Andersson, 1993). Typical examples are references to time (now, today, yesterday), spatial references (here, there, left) and pronouns (I, she, it).

Why, then, are such common words of any interest to this study? One of many problems one faces when analysing interaction is to account for how the participants make use of the context. For instance, does it make any difference whether a discussion under scrutiny takes place within the setting of a school or at home? Video material increases the possibilities of moving towards the perspective of the participants, but it is still up to the analyst to account for exactly what in the surroundings is relevant to the participants. One approach to this complex issue is to study the deictic terms. By focusing on these words, the analyst gains access to sequences where the participants themselves actively refer to objects in the present situation. In line with this argumentation, Hanks (1992) describes deixis as something that organises the field of interaction into a foreground upon a background. It creates a Figure-Ground relation, where the thing referred to is highlighted for the other participants and thus ends up in the foreground.

In the case studied here, a large number of deictic terms can be found. The participants often communicate in a way that involves the concrete environment. This frequent use of deictic references is an observation that corresponds well with earlier experiences of this environment (Ivarsson, 1999; Lilja, 1999). That this mode of communication is connected to the technology seems reasonable, but the question is how. One hypothesis is that the visual and interactive aspects of the technology facilitate this kind of language. The visual representations can be seen as restructuring the communicative patterns among the participants and thus contributing to the creation of other forms of activities. Not having to rely on linguistic descriptions to the same extent enables even younger students to take part as more central participants. In these activities, the use of deictic reference also becomes a functional and convenient way of reaching transitory agreements.

Isolated Activity

When the teachers present the problem of recursion, they use the visual representations as a basis and articulate the specifics with the aid of deictic terms. This creates an approach to the problem that the students can easily follow. Given the complexity of the problem, in relation to the students' level of education, this could be seen as a skilful achievement. The question remains, however, whether the students are given any possibilities of handling this problem at a conceptual level. If this episode remains an isolated event in relation to their normal education, one could seriously question its value. The risk of such isolation is considerable and one of many reasons for this is the kind of local language used.

The different kinds of experiences the teachers have of recursion vary in character. One kind is not unlike the situation facing the students, involving palpable manipulation of symbols. Another kind, more 'theoretical' in character, comprises particular ways of talking about these phenomena and involves specific linguistic distinctions or *concepts*. One of the advantages of theoretical concepts is that they, in their capacity as linguistic tools, can be used in different contexts with some meaning preserved. Or put more correctly, since they maintain a relation to earlier contexts, the meaning of concepts can more easily be recreated in new situations, a process sometimes referred to as recontextualisation (van Oers, 1998). When using specialised terminology, one can connect to theoretical traditions and thereby associate with situations and events beyond this one, both past and future. This is in sharp contrast to the deictic expressions, whose meanings are produced with more local means.

In the examined excerpts, it is obvious how the students consistently work with the digital environment as a basis. The technology functions as a point of reference to whatever knowledge is brought to the fore. From an educational perspective, the danger of this is that the students may do the work, without ever considering facts that apply to the world beyond the screen. The activity lacks an overall language that points towards a future, towards a possible continuation and connects this activity to other contexts. Or, to use Wittgenstein's sententious words: 'Teaching which is not meant to apply to anything but the examples given is different from that which "*points beyond*" them' (Wittgenstein, 1953, no. 208). In the case studied, the students concentrate on the example, but never aim beyond it.

Illusory Intersubjectivity

Another aspect of the presented material concerns the character of the cooperation that goes on. For any cooperation to take place there has to be a certain amount of mutual understanding or, as it is also called, intersubjectivity. Some researchers are of the opinion that this mutual understanding is never complete; we can never fully understand each other. It is, rather, a question of sufficient understanding for the moment, sufficient enough to move on in the interaction that takes place (Wittgenstein, 1953; Rommetveit, 1974). This way of looking at the matter corresponds well with the communication examined here. It is reasonable to say that there exists some intersubjectivity, or common comprehension of the situation between the students and the teachers, but not more than is enough to keep the conversation moving.

Returning again to the deictic language, this is very open (Rommetveit, 1974) and may allow a number of interpretations. In this case, the consequences are that the participants fail to recognise how far apart they stand. The students are never given the possibility to observe any distinctions that could be of vital importance in future encounters with recursive phenomena. Instead, they are temporarily trapped in a local and non-conceptual world. At the same time, the teachers risk interpreting the students in theoretical terms (Wyndhamn, 1995), as if their actions were about the concept of recursion. The latter becomes a form of over-interpretation that disregards the perspectives of the students.

The reasoning being performed by the students and the teachers, respectively, can be seen as two almost separate lines of reasoning. These lines converge in the deictic expressions and the actions that are connected to the activity of programming. What makes these lines of reasoning so different from each other is that the students and the teachers have access to differing resources for their interpretations. In the material, the students almost exclusively use earlier experiences from the technical environment when struggling with the problem at hand. The teachers, on the other hand, can benefit from earlier experiences and ways of talking about recursion in other situations.

Concluding Comments

The most important contribution of this study is to offer a critical voice, to the common expectation that, aided by equipment of this kind, students gain *practical experience* of complex processes. In the light of the results described above, this argument is not supported. If these complex processes are not accompanied by a theoretical language, the aspects that are 'advanced' will end up on the same level as those that are trivial and arbitrary. Nothing will necessarily stand out as more important to the students—the colour of the icons could be of the same relevance as their way of functioning. In spite of the many advantages of digital technology, this study constitutes an example of a situation where the technology cannot provide the students with the guidance necessary. This observation is not entirely new, however, Levinson and Murphy (1997) make the same remarks when discussing conceptual development in a design and technology project. The novelty here is (hopefully) the detailed description of what such a process can look like.

In connection to this theme, the constructivist position that states that students themselves will *discover* the underlying principles built into the technology (Papert, 1993; Jonassen, 2000) seems somewhat awkward. This position takes for granted that every student, in a few years, could discover principles that have taken philosophers and scientists millennia to sort out (Säljö, 2000). From the theoretical perspective guiding this work, such a stance is most problematic, and the counterargument would be that we must take short cuts. One of these short cuts is language and, with the aid of this, our theories. In this respect, learning about recursion (i.e. beginning to regard a certain phenomenon as a recursive process), can be seen as a gradual participation in specialised practices—it is to become a member of practices that already have established ways of talking and acting, with reference to a limited part of the world (Roth & McGinn, 1997; Säljö & Bergqvist, 1997).

Finally, in defence of the technology stands the observation that the experience students gain from working in this environment could form a good basis for further reasoning. Actually, it seems as if the visualisations in this case could offer students access to mathematical worlds far beyond those furnished by normal textbooks. This, however, requires an active and attentive teacher mediating the activity. Someone has to help students overcome the local character of things. Abandoning this task in favour of technology might transform the learning environments into *digital koans*, interactive riddles that keep our students in local and non-conceptual worlds—a condition somewhat jestingly described as 'kids in Zen.'

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NOTES

1. 12–13 years of age.
2. For the reader not familiar with programming, a function could be likened with a recipe; the name would then be the dish in question and the instructions would be the ingredients and the manner in which they should be prepared.
3. Excerpts 1 to 7 are all parts of the same sequence. With respect to the interested reader no utterances have been omitted.
4. The word 'deixis' stems from the Greek word for *showing* and *pointing out* (Rommetveit, 1972).

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