Kekule is describing how — in 1890 —
he discovered the benzol ring. It was
not the text which made him see the
light. On the contrary, the new insight
was born from an associative, half
conscious perception of visual dynamic
images: the snakes dance, and one of
them, and notice this — mockingly —
gets hold of its own tail. Was it
mockingly because the scientific
discovery was right there before his
very eyes, but he could not see it because
of all the words? It was seeing with
the mind’s eye which was the basis for a
new understanding, and it was
imagination which played a crucial role
in bringing forward a new scientific
discovery.

It is this ability to imagine things,
to disregard the written word, and see
the meaning in a visual image which catches my attention, because the
human being is a visual being, it is with
the eyes we meet the world. And
whether it is images in the outer world,
or images seen with our mind’s eye, it
is visual perception which rules.

Yet we live in a language culture, a
western culture in which knowledge
acquisition and learning is understood
as being based in language. The
technological development, however,
points towards a future of multimedia,
with a growing use of icons, dynamic
graphics, video etc. Whether one speaks
of advanced systems designed for
power-stations or for educational use,
increasing amounts of information will
be in the form of visual dynamic images,
which have to be read and understood.
Systems will be multimedia visual
systems. This means that alongside,
and interacting with — sometimes
overriding — the language culture,
there will be an image culture.

Once upon a time the human
species did not possess a written
language. They communicated and
expressed their knowledge by drawing
images on cave walls. Over thousands
and thousands and thousands of
generations, the humans have invented,
developed and refined languages. At
the same time we have also developed
and refined our cognitive qualifications.
Instead of communicating via drawings
we can express knowledge through
language. We can read the thoughts
and ideas of other people and through
this rather abstract mental activity try
to understand the message. Thus
developing language as a tool for
communication and for the intellect,
definitely enhanced our cognitive
development.

There is every reason to expect that
the new visual multimedia will demand
new cognitive qualifications. A very
essential one will be the ability to
critically read visual images.

**TEXT AND/OR GRAPHICS**

In a research project I wanted to carry
out an empirical investigation of the
influence of image representation
and written information on cognitive
processes. To enhance this goal I chose
a simple software program in which
text/dynamic graphics were integrated.
This would allow the learner both a
symbolic approach and/or a graphical
approach to the task.

The research was based on a
qualitative investigation of 36 novice
users — age 15–16 — who were
videotaped during their work with the
computers. The empirical data were
collected in two steps. First a group of
schoolchildren who worked with the
Danish edition of Logo in their math
classes was investigated. The second
step was an investigation of a group of
adults who participated in a computer
course.

The novices were given an
introduction to computers with 6–10
hours hands-on experience. This
included instructions from a teacher
and they worked through different
examples together with the teacher.
Following this the participants were
given different problems to solve. They
worked in pairs, and the following
sources of information were available
to them:

- verbal explicit help and
  instructions;
- instructions on blackboard;
- written explanations in the form of
  a manual;
- a book with exercises including
  explanations and illustrations;
- a list of system commands; and
- the information on the screen being
  both text and/or graphics.
THE SEDUCTION
The analysis showed, that irrespective of age, there was a clear preference for the dynamic graphics. Only very few were able to handle the programming approach. Nevertheless they succeeded reasonably well in solving problems. It was not always the problems posed, but they wrote functional programs. However, this happened only if they relied on their visual perception, because the words, worked as a hindrance (Nielsen 1987).

Initially this was no problem, because they were clearly fascinated by the dynamic images. They all possessed, one may say, the very special ability of allowing themselves to be seduced by the graphics (Nielsen & Lisbeth 1985).

THE ENCHANTMENT
The dynamic graphics functioned as an enchantment, and to some of the participants this also worked as a hindrance. This happened when they got 'caught' by the graphics, when the visual images ruled. The graphic forms and in some cases also the dynamic movements captured their attention to the extent that they never sought beyond the dynamic image, hence it was not made the object of analysis. The immediate visual sight was sufficient for them. As a consequence the dynamic graphics led to a fixation (Nielsen 1988).

THE ENHANCEMENT
To other students the dynamic graphics would promote the learning process. When successful they would move beyond the immediately perceivable and try to grasp the information embedded in the graphics. They would stare at the screen, their eyes glued to the cursor, heads nodding, following its moves. They would venture interpretations, voice assumptions and comment on the stepwise movements. 'Yes, that's it, we are turning to the right, now it should finish the circle and move out again' (Nielsen 1987). They would solve the problems by reading and debugging the dynamic graphics — not the programs. In these cases I found that the dynamic graphics enhanced learning, hence understanding.

THE PRIMARY SOURCE OF INFORMATION
However, whether they succeeded or not, the dynamic graphics were the most important source of information. It was primarily the dynamic graphics — not the program or the priority defined logic embedded in the programming, nor other kinds of information and explanations — which they would rely on, respectively read and debug.

Yet the adults would state during an interview carried out prior to the work with computers, that given a choice, they would primarily rely on written instructions. After the work with the computers were completed, they stated again that the written instructions — exercise book or manual — had been the main information sources.

It is with the eyes we meet the world. And whether it is images in the outer world, or images seen with our mind's eye, it is visual perception which rules.

Confronted with the videotapes, they were surprised, some of them even expressed shock when realising that they primarily relied on the dynamic graphics and the illustrations in the exercise book. They lived in a language culture, and were not aware of the extent to which they relied on information in the form of visual images.

VISUAL THINKING
Yet they were able to write functional programs. But the analysis also showed that it was not sufficient merely to see the graphics. They also had to be able to operationalise the visual knowledge gained, that is they had to be able to read the dynamic graphics. Failing to read the information embedded in the graphics, they were lost.

To explain some of the cognitive processes at work, I should like to introduce the concept of tacit knowledge (Polanyi 1968).

INDEFINABLE INSIGHTS
M. Polanyi has given exceptional and profound contributions to the discussion on the nature of scientific knowledge. He makes a distinction between logical knowledge and psychological knowledge and according to Polanyi the latter is the ground upon which scientific knowledge rests. He discusses 'the indeterminacy in scientific knowledge' (p. 27) and argues that fundamentally knowledge rests upon an indeterminacy in content, in the coherence we see which will always be vaguely defined, as well as in the data upon which we base our results.

Polanyi perceives science as an 'extension of perception', a way of seeing reality in gestalts, and in his analysis he focuses upon the cognitive process of visual perception and shows through examples, that what is true for scientific knowledge is also true for other kinds of knowledge.

Polanyi suggests that 'explanations must be understood as a particular form of insight' (p. 38). This implies that there are other kinds of insights, other kinds of understanding and other kinds of knowledge. It is the other kinds — the tacit knowledge which are of special interest to Polanyi, and he introduces these non-explicit or indefinable insights through examples of indeterminacy in knowledge, where he shows that 'we know far more than we can tell' (p. 30).

TACIT INTERFERENCE
The development of tacit knowledge and the tacit inference is intertwined with our awareness, and Polanyi distinguishes between focal awareness and subsidiary awareness. Reading this text, the focal awareness is not oriented towards each single letter, nor towards each single word or the sequence of the words. All of these elements function as subsidiaries for the focal awareness which is oriented towards what the reading is all about: the meaning of the text. The relationship between the letters, the words, the sentences is created via a tacit inference, via the cognitive ability of gaining insight. It is the same kind of tacit inference which takes place when one is looking through a stereoscope. Looking with only one eye, one sees one image. Looking with
the other eye, one sees another image. Looking with both eyes, an image which — one may say — is not there, is created. The eyes see a relation or rather a coherence which is created by the tacit inference from the two images, and born — or imagined — in a third image. Thus one sees more than what is visible, and the underlying process is that of visual perception, of trying to gestalt, to make sense of what is seen.

MORE THAN JUST SEEING

With this understanding of visual perception, it should be no surprise then, that the most important source of information was the dynamic graphics. The students were seduced by the graphics. Yet information in the form of visual images does not always enhance insight and understanding, though it may enchant. To some of the students the seduction would turn into an imprisonment. This could be a result of an expected graphical outcome not showing up on the screen. One could almost say that a breakdown in the ‘communication’ occurred. They did not seem to have fully grasped the wholeness, or the interrelatedness of the graphics. As a result the process would often be trial and error and eventually haphazard changes. Most often they would get lost in the attempts to change the program in order to obtain a wanted result. As a consequence, they lost the overall view, and sometimes experienced the frantic changes as if they were moving in a maze. Others were so fascinated by the dynamic graphics, that even when the cursor’s only moves were to circle around itself, they would laugh with expectant smiles on their faces. ‘Did we ask it to do that?’ They would have their eyes glued to the screen, and with screams of laughter repeat the experience, ‘let’s make it do it again’ (Nielsen 1986). Or they would be so fascinated by the graphical shapes, that they would perceive the form, no matter what, as the meaning of the activity. As a result no analysis would be attempted and not much understanding would be acquired.

The students’ awareness became ‘frozen’ in the graphical result on the screen. Attempts of indwelling were few, because the immediate fascination was so strong.

The students who, with success, relied on graphics, did so because they allowed their visual perception to rule, following the dynamic graphics so carefully that they were ‘down there in the screen’, moving around with the cursor. ‘Pouring one’s body into it’ is how Polanyi describes the process (p. 33), and he argues that only through this ability to project our senses out into an external space is essential knowledge gained, which could not be acquired by an act of detached intellectual contemplation. In this act of indwelling, the students do not focus on each particular step of the cursor, but these movements rather function as subsidiaries guiding the awareness away from each step and towards an integration of all the particular movements into an image — a coherent gestalt. It is a perceptual integration established through an inference.

Of course the students, when looking at the screen, are aware of each step of the cursor. The fact that their eyes are following the cursor around, and their heads are nodding, tells us that. However, this is not the focus of the attention, or rather they are aware of the artificial steps in some unfocal way. The steps are perceived in relation to the whole, and the students make sense of what they see by establishing a coherence between the steps. Part of what they see is incoherent, but they gestalt an indeterminable coherence by imagining a joint image.

Their inference is based on the graphics which lead to understanding. It is not the result of detached contemplation. On the contrary, this is a spontaneous event, it happens suddenly and is never explicitly verbalised. Polanyi speaks of it as a tacit inference and sees it as a result of intuitive processes, of knowing more, or maybe seeing more that there is to see.

DISCUSSION

I should like to turn back to the question of visual thinking and I will suggest that thinking is neither language, nor pictures nor logic. These may function as subsidiary tools for the thinking. Thinking I have come to understand as ‘condensation of meaning, insights which initially neither exist in language nor in pictures’ (Dirckinck-Holmfeld & Nielsen 1992). We have all experienced how a very clear idea of how to proceed with a given problem, becomes completely muddled up when we try to write it down on paper.

New insights and understandings may be perceived as ‘flashes’ where one sees something which one has never seen before. Like Kekule, who saw the snake dancing before him, and getting hold of its own tail. A state or experience like this is indeterminate, irreversible and tacit.

Under many conditions this kind of tacit knowing may be superior. However, in other connections tacit knowing is fundamental, but not sufficient in itself. In learning processes the aim will be to penetrate as deeply as possible into the understanding based on tacit inference, in order to acquire a conscious and articulate understanding of the tacit inference.

In order to open up for profound and fundamental understanding multimedia may enhance the processes because it embodies an element of seduction which enhances the learner’s access to indwelling. It also offers a way to concretise and visualise dynamic images which may enhance the student’s comprehensive view. Just as it is a force and because it may stimulate exploration. However, the seduction is dangerous if it lures the students into focusing their awareness on subsidiaries, instead of the meaning of the message.

This ambiguity will also be true of sophisticated designs of the future, and as pointed out, it is not sufficient to become enchanted and merely see, one has to be able to read the images and
see coherences where no coherence is. I will suggest that an essential cognitive qualification needed in the interaction with the multimedia systems is that of visual operational thinking. Human beings already possess this ability to grasp graphics, only to some extent it needs to be further qualified.

END NOTES

1 There is, of course, a difference between actually seeing the blue sky and imagining seeing the blue sky. But for now, my interest is the cognitive processes which make sense of what one sees, whether it be actual or imagined.

2 The Logo program was very easy to handle. The philosophy behind the design was that a child should be able to use it without too much practice. Exactly because it was designed in order to promote easy access for children it was, in terms of software development, a very advanced tool.

3 The advantage of this method is obvious. The working process I captured, in detail, on the screen. The total process is visible, an 'internal' documentation. Others may work with you on the interpretations. The participants themselves—as in this case—can participate in the analysis. Especially when breakdowns occur, this has proved extremely useful.

4 Example of an illustration showing a triangle which was turning and at the same time growing in size, was shown. The instructions would then be try to write a program which would execute a similar form.

5 The tapes showed that only a young man of age 15, after make a change in a subroutine, mentally integrate it into a super-routine, and predict the outcome.

6 This was even true one year later, after approximately 50–60 hours of programming experience (Nielsen 1989). The preference for graphics is also documented in a working paper by Hoyles and Noss (1987) — though this is not a conclusion the authors draw.

7 Of course he had to state it explicitly, in order to communicate the experience to others. This is fundamental for all human life. Language is an extremely important tool for the intellect, in communication etc. However, this is not the axe I want to grind here, my aim is to discuss the role of visual thinking.

8 Another necessary cognitive qualification is the ability to navigate in these systems and keep track of where one is. This qualification I have termed: a mental spatial mapping ability.

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