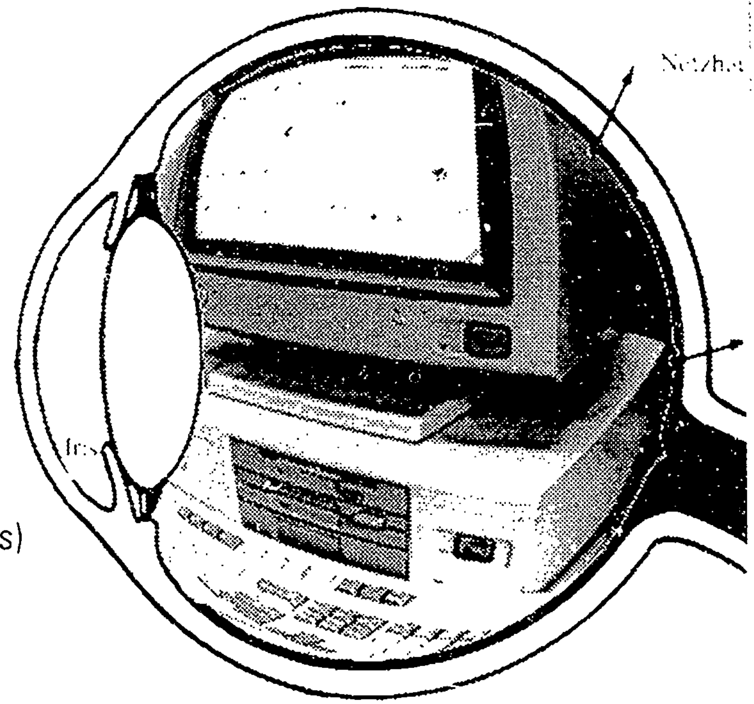
Principles and tools for instructional visualisation



Jan Schoenmaker
Ivan Stanchev (eds)

faculty of
EDUCATIONAL SCIENCE AND TECHNOLOGY
Andersen Consulting - ECC
The Netherlands

University of Twente
ANDERSEN CONSULTING
ARTHUR ANDERSEN & CO. SC

Principles and R&D Aspects in Instructional Visualisation

Ivan Stanchev

Communication - a model of the process

How can we be clear and comprehensive in summarising the communication process in a single model ? We can't. So many complexities apply to human communication that we must settle for something less than completeness and clarity. But we can summarise some of the most significant aspects of the process, and we can sharpen our awareness of what goes on when we attempt to send and receive messages.
Contemporary scholars have offered dozens of definitions of communication, and it would be arrogant and unprofessional to come up with "a definition to end all definitions"; however, we offer this working definition of effective communication:

Effective communication occurs when a sender transmits a message and a receiver responds to the message in a manner which satisfies the sender.

Note a few implication of this definition:
- It focuses on ***applied*** communication. This brief definition deals with getting results through communicating effectively in social organisations; it does not deal with theories, experiments or philosophies which go beyond that goal.
- It accepts the ***satisfying*** concept. In social organisations, as in almost all human situations, we often accept what is less than perfect. As long as a situation becomes productive or meets our basic goals, we usually settle for it. Teachers and instructors tend to settle for a productive understanding, rather than pressing for clarification of every historical, linguistic, philosophical, or technical aspect of a communication. The time and energy involved in reaching a "perfect" understanding (assuming for the moment that it is possible) would be too costly.
- It assumes a ***feedback*** *loop*. In order to realise satisfaction, parties must get some sort of confirming response. This can be verbal or non verbal, written or oral. It can occur through observation, evaluation systems, dialogue, and so on, but somehow the sender must experience verification of an adequate understanding of the intent of the message. Of course, in the process of giving feedback, the receiver becomes a sender and the original sender becomes a receiver. In addition, the original sender may modify a message in the light of feedback. But at each stage, our definition assumes sufficient response to confirm adequate understanding.

The key word in the definition is the term "message". A "message" is a pattern of signs (words and pictures) produced for the purpose of modifying the cognitive, affective, or psycho-motor behaviour of one or more persons. The term does not imply any particular medium or vehicle of communication.

When we pay attention to a stimulus, we tend to give it an interpretation, whether the stimulus is verbal or non verbal. We base our interpretation on such factors as our general backgrounds, our loyalties, our vocabularies, our education, our expectations, our personal interests, our values and our prejudices. Because of such factors, distortions often occur as messages filter through channels. But by being aware of such factors, we can work toward encoding and decoding more effectively, and toward reducing "noise" in the communication process.

Visualisation and perception

In a letter to Jacques Hadamard, a friend of him, Albert Einstein speaking about himself wrote that words in their written or oral form did not play a significant role in his way of thinking and that to him the basic elements of thought were definite signs and symbols(Einstein, 1953).

Mastering of techniques for information visualisation and the ability to present this information as an explicit and simple drawing have great importance in many spheres of human activity - research, design and construction activities, books and printed matter layout, etc. Visualisation of information takes a particularly important place in educational systems since psychologists have proved that visual perceptions play a most prominent part in information memorising and reproduction and that memory is the result of the received perceptions which according to some theorists can · apportioned in the following way:

- 75 % visual perceptions;
- 15 % aural impressions;
- 6 % tactile perceptions;
- 3 % sense of smell, and
- 3 % taste.

All that is of great importance when interactive courseware is being thought out and designed since the computer screen is the main source of information in the user's communication with a program. If the program's creators have not made it visual enough it could be difficult for the trainee to interact with it without using additional information from other sources (for example, from the teacher or a guide for work with the program). In contrast, the design of visual objects demonstrating the program's potential and content can improve the ease of comprehension and sound memorisation of the information contained in the program.

The process of artistic designing (visual design) is very close to the theory and practice of fine arts - it is subjected to the same principles with regard to the means of the composition (symmetry and asymmetry, metrics and rhythm, contrast and nuances, proportions, scale, colour, texture, etc.). The observation of these principles increases the strength of the impact of the information apprehended - a fact well known and used in the fields of ergonomy, aesthetics and design. On the basis of these principles a number of important and fundamental principles in the visualisation of information can be formulated:

The principle of conciseness. The graphic means for information presentation should contain only such elements which are indispensable for conveying essential information to the viewer and this information must be comprehensible for it represents the visual accent of the basic composition elements. It is useless to try to draw attention to the most important characteristic features of a situation if they are surrounded by superfluous visual distracters having no bearing to them and hindering the apprehension of the essential (see Fig. 1).

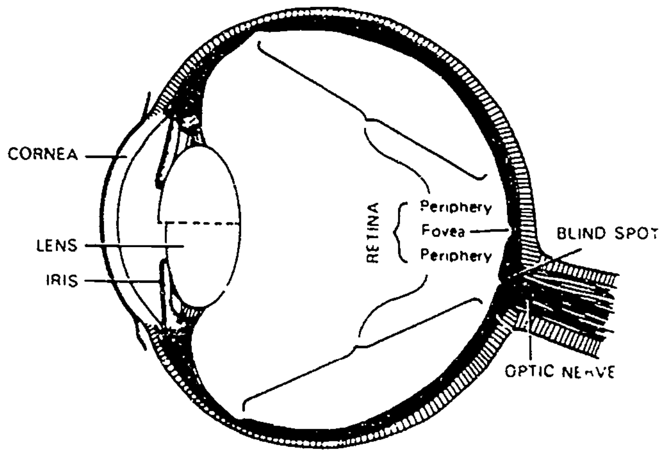


Figure 1

The principle of generalisation and unification. The basic forms for graphic presentation of information must not be needlessly broken to pieces or include elements designating superfluous details from the standpoint of the presented information. This form must be rationally generalised and the symbols denoting the same objects and phenomena must be unified, i.e., they must have a unified graphic solution (see Fig. 2).

Figure 2

The principle of accent on basic notional elements. In visualising information the elements most essential for information comprehension by the viewer should be set apart in size, form and colour. In some cases it is even possible to allow a conscious breaking-down of the proportions of symbols' sizes with respect to the real objects depicted by them (see Fig. 3).

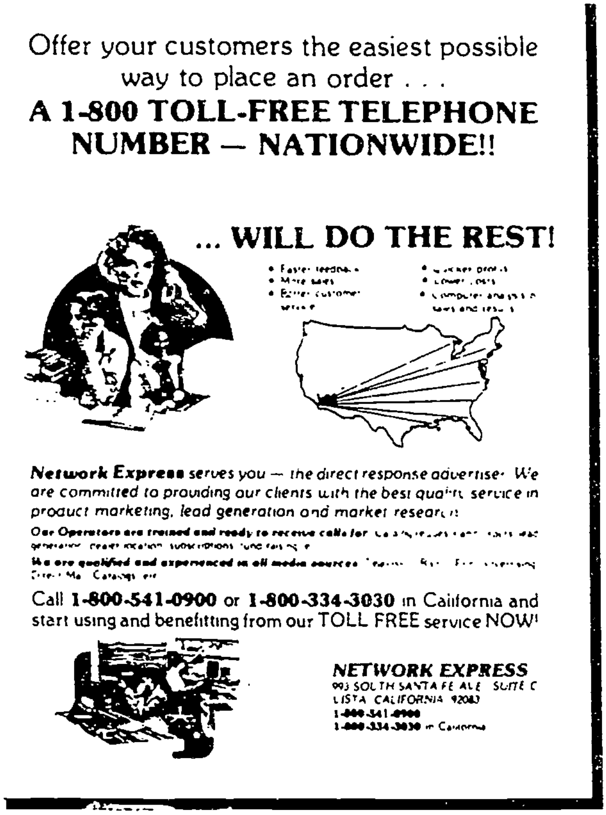


Figure 3

The principle of autonomy. The graphic presentation of information concerning autonomous, independent objects or phenomena should be set apart and clearly differentiated from the remaining components of the image. In practice it means that the decomposition of the complex graphic information into separate simple images facilitates considerably its perception and comprehension (see Fig. 4).

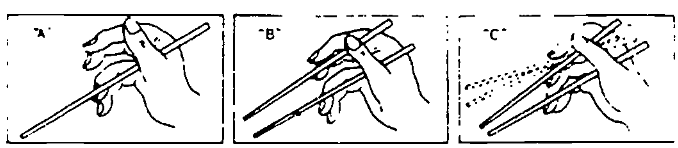


Figure 4

The structural principle. Every autonomous component taking some central, crucial position in the graphic expression must have an exact and easily remembered structure differentiated from the other components. This structure, as well as the structure of the whole graphic image must conform to the logic structure of the real object or phenomenon's decomposition (see Fig. 5).

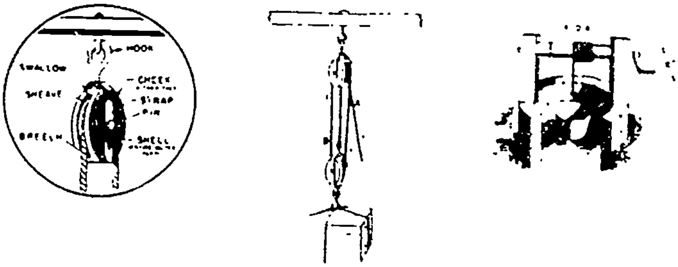


Figure 5

The phasic nature principle. The behaviour of dynamic objects and phenomena presented through the means of information visualisation should be decomposed with respect to time and space. It helps not only to understand and acquire the mechanism of this behaviour but provides a procedural logic which should be presented with the assistance of various graphic rneans (see Fig. 6).

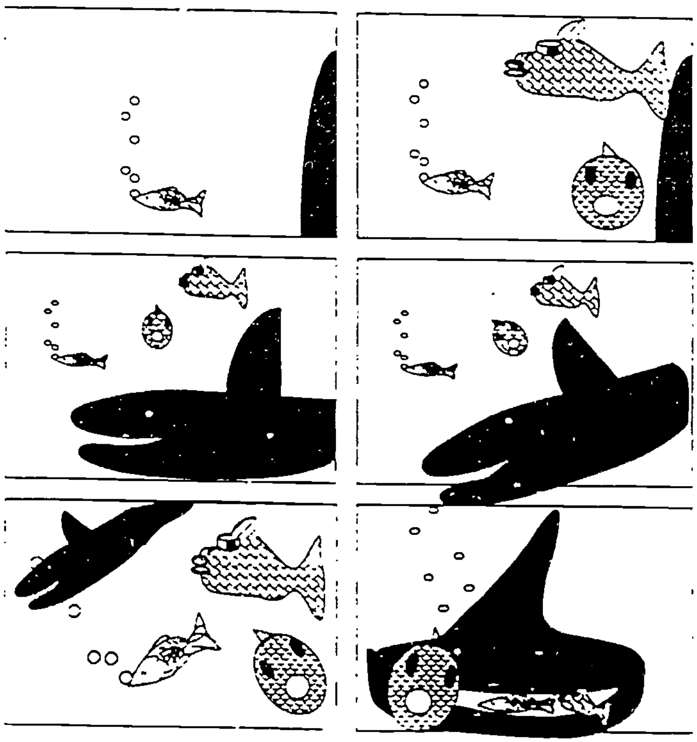


Figure 6

The principle of use of fixed associations and stereotypes. In creating graphic forms for information presentation the stable, habitual associations between the symbols and the objects and phenomena designated with them must be recognised as well as the stereotypical reactions of the viewer to definite symbols and signals. It means that where it is possible one must not use abstract, conditional signs but symbols which lead through association to the respective objects and phenomena. On the other hand, however, one must bear in mind that the naturalist, detailed presentation of the outer appearance of the objects keeps the viewer's thought on the outer similarity with the object and impedes the realisation of the more essential, from the point of view of the presented information, characteristics and regularities (see Fig. 7).

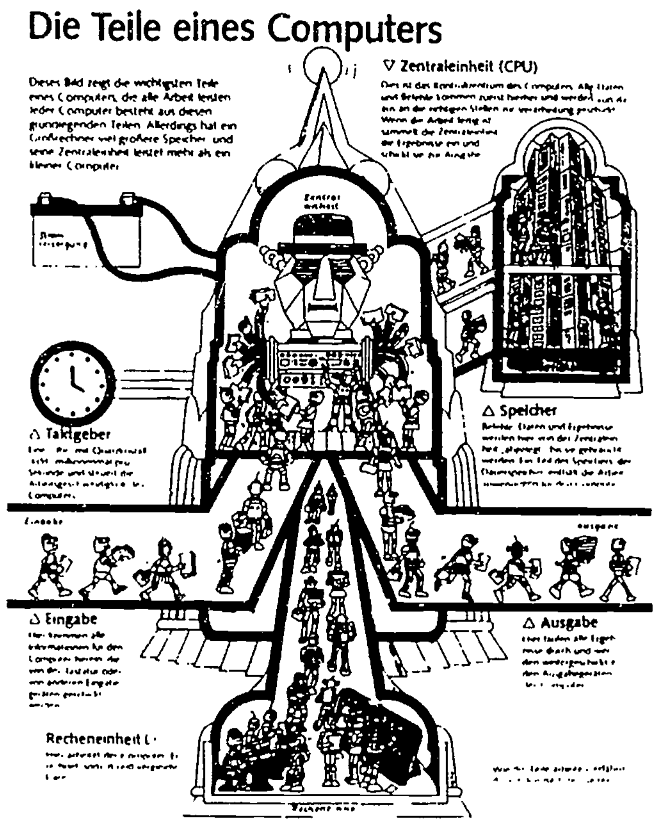


Figure 7

How can abstract principles be applied to concrete instructional problems? One means of facilitating this transfer is to state both propositions (both the principle and the problem) in parallel forms. This form can be generalised as: "What conditions lead to what results?". In (Fleming and Levie, 1978, pp.15-18) is given a excellent example for applying this approach using the basic principles of perception for some general guidelines for the instructional designer.

Basics of visual communication

Specialists in the field of visual communication maintain that a drawing is worth thousands of words and this is really so provided the drawing is good. The difference between words and a drawing is that with the assistance of words we narrate while a drawing shows. However, in order to achieve the desired result the possibilities of the graphic language must be mastered. If the meaning of a text is revealed through words, the illustration "speaks" in the language of forms. The communicative possibilities of the graphic language can be understood if we analyse the goals of visual communication, i.e., if we try to answer the questions What? How? How much? and Where? with the help of graphic expression (Fig. 8):

- **What** does the object represent? What is it? - it is a question which refers above all to the *outer appearance* of the object, its physical *structure* or the logical relation of its parts to the whole. Most often questions refer to the visual perception of the object's properties, but they can also refer to such properties which are invisible under ordinary circumstances and also to definite abstract notions connected with the *organisation* of the object itself.

- **How** does one or another object operate? This is a question which concerns its *physical movement*, the *logic's of functioning* of its separate parts within the frames of the whole as well as the *process of functioning* of the whole object as a sequence of interrelated conditions. In these cases the demonstration of actions in static images requires the use of symbolic forms displaying movement. It applies with equal force both to real physical objects and phenomena and to ideal models presenting an abstraction of reality.

- **How much** refers to the quantitative characteristics of the object, i.e. to the physical *dimensions* of the object, the *quantitative relationships* between its components and elements as well as to their *correlation to the whole*, the tendency of alteration of the physical characteristics, etc. The quantitative analysis of the object and its image involve compulsory a process of abstraction.

- **Where** is a given object located or a given phenomenon take place? This is a question which refers to the *place* of the object, its *location* in space, its *position* with respect to other objects. Very often the differences between these three characteristics are difficult to detect but the basic questions relevant to them can be differentiated according to their functional meaning.

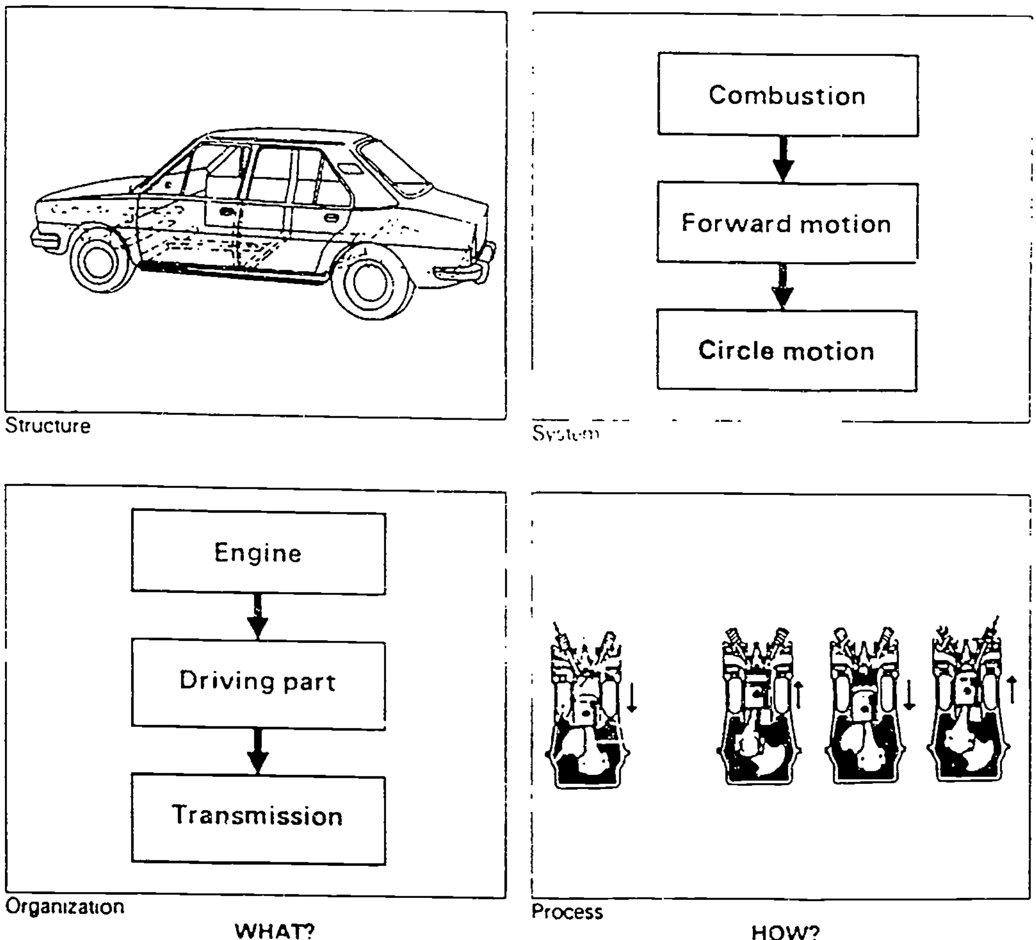

Combustion
Forward motion
Circle motion
Structure
System
Engine
Driving part
Transmission
Organization
Process
WHAT?
HOW?

Figure 8*

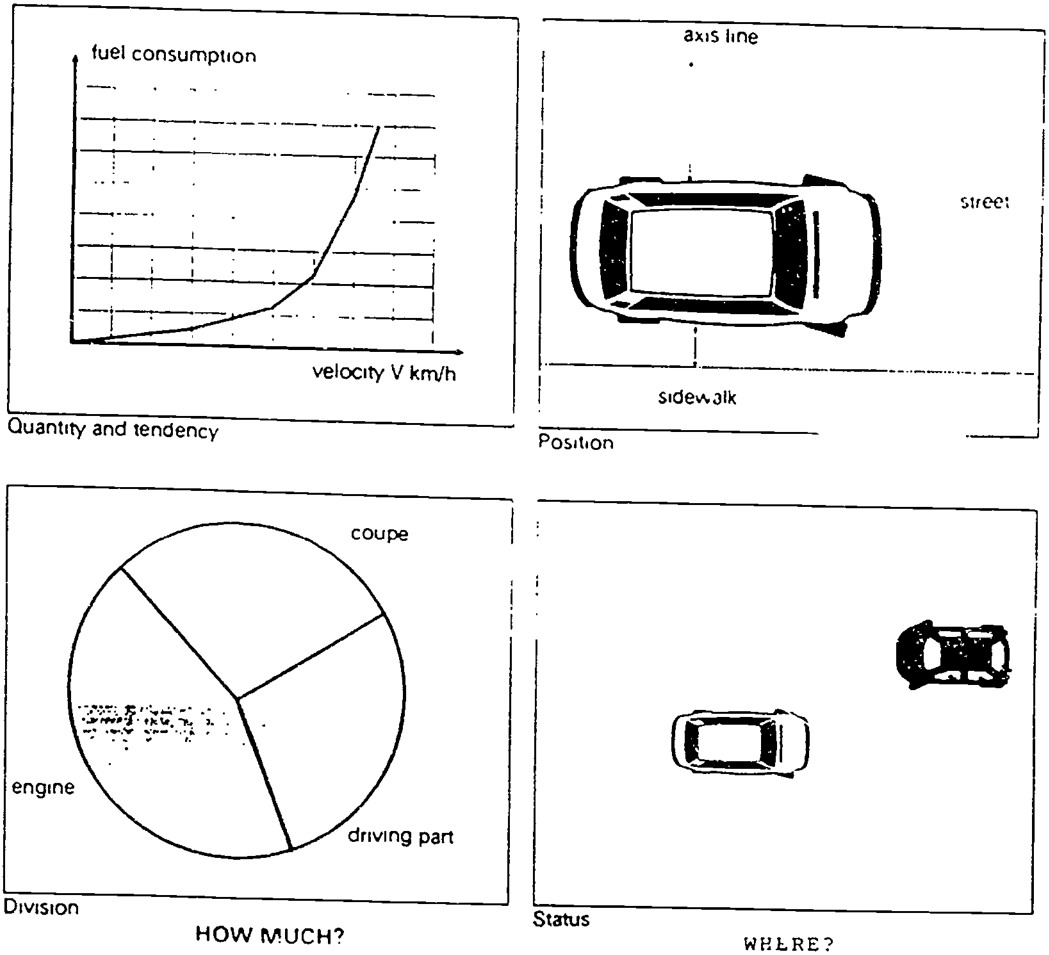
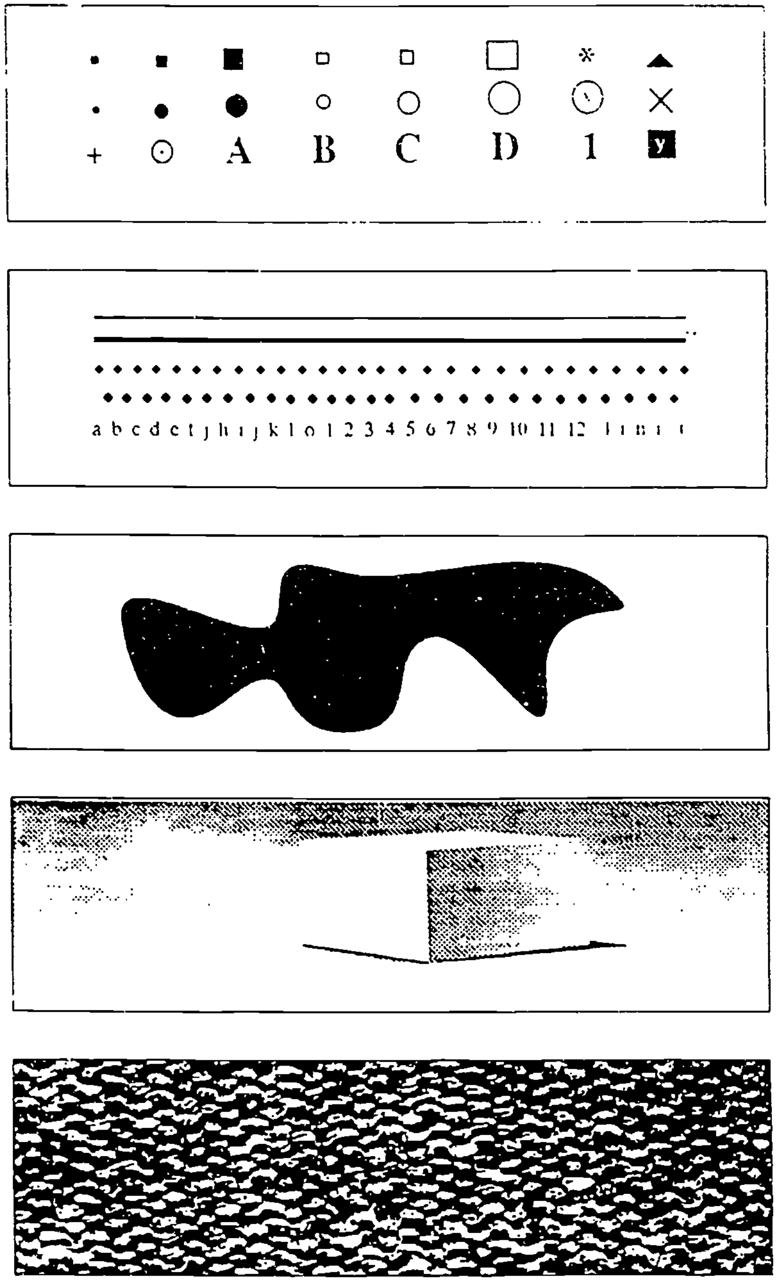


Figure 8[b]

<u>Visual language</u> has like any other language a syntax's, semantics and pragmatics. The lowest level elements of forms, comparable to the characters of verbal language, are well known from geometry - **point** which has no dimensions of its own but shows a place, location and position, then **line** as a one-dimensional image. On the intermediate level, comparable to words, configurations of the lower level element get a basic meaning.



Point

Line

Flat shape (spot)

Tone, tonality

Texture

Figure 9

On the high level the "words" of visual language combine to form expressions. Through line we most often show direction, stretch or movement. As an element of the word stock line can be used also to depict trajectories and routes, to designate boundaries and divisions. The regular and irregular geometric figures as well as the plane forms are a two-dimensional image of some type. Space occupied by them coincides with a definite area of the drawing. In this sense the figure as an element from the dictionary of the graphic language is used to designate contours, area, outline, frame, etc.(see Fig. 9).

The definite hue, i.e. a relationship between the degrees of black and white as well as the colours, affords us a possibility to distinguish between separate elements of the object or to accentuate on the basis of contrast. Smooth transition and use of light shades allow us to describe volumetric forms and perspective changes (see Fig.10).

The texture of the graphic image is in fact the surface structure of the drawing and here we can use both abstract and symbolic and descriptive textures. In practice, they denote properties of the physical surfaces of the object and are usually used with other elements of the form - most often they are combined with colours.

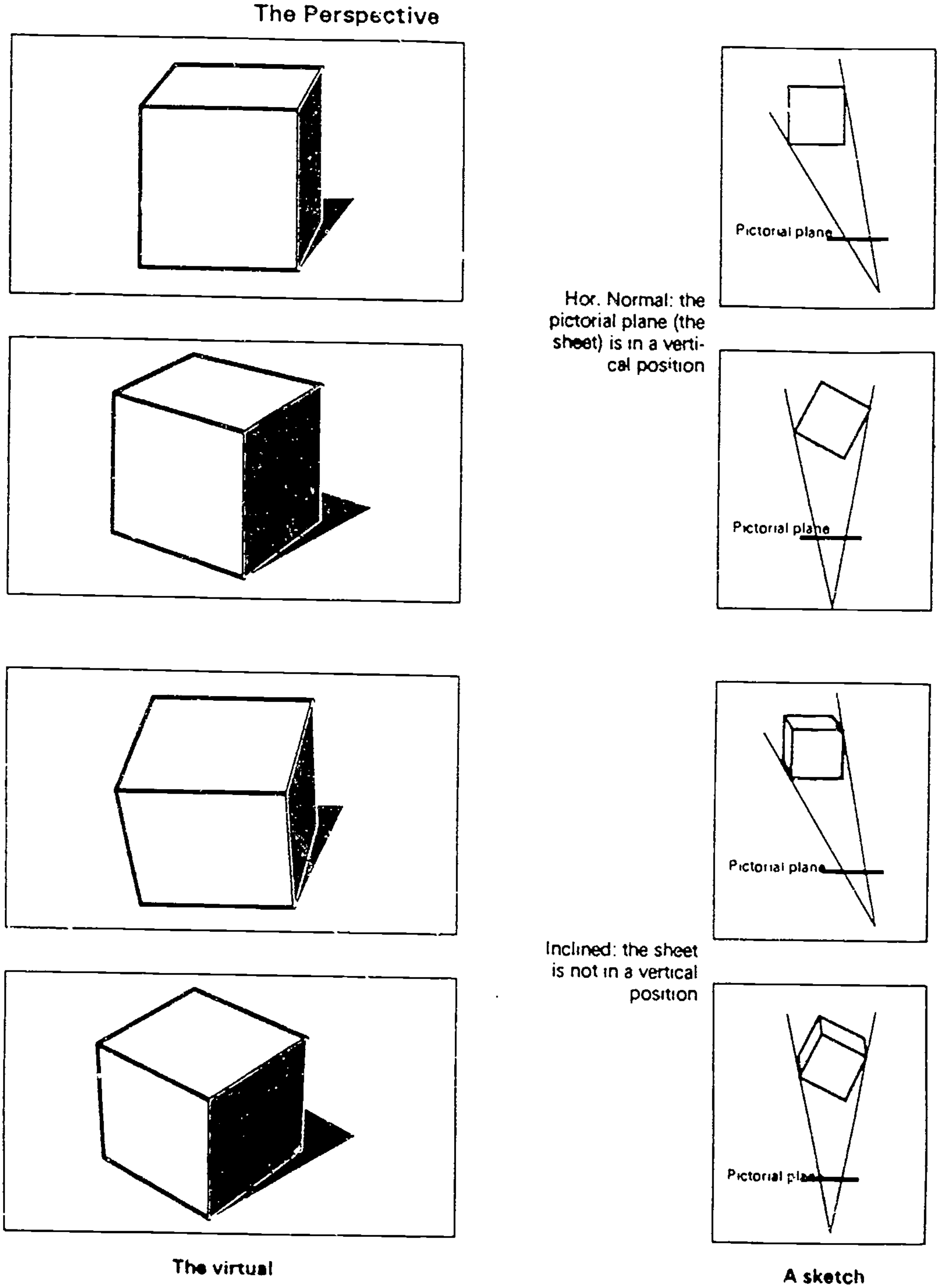

The Perspective
Pictorial plane
Hor. Normal: the pictorial plane (the sheet) is in a vertical position
Pictorial plane
Pictorial plane
Inclined: the sheet is not in a vertical position
The virtual
A sketch

Figure 10

Graphic language together with its elements is not created for its own sake - the form, the space and the visual interaction are means for presentation of definite ideas, objects and phenomena. That is why visualisation always begins by setting some definite goal and then a content corresponding to the goal is chosen which is translated into the language of visual forms. It is afterwards that the drawing is constructed and in it the visual language is wholly used to develop and specify the visual image and its transformation into a visual model. That means that the **conception** or the visual idea, the **artistic design** and the **graphic execution** are the three main stages in the process of information visualisation.

What are the practical conclusions that we should drawn when visualising the information in interactive programs? Above all the conclusions are relevant to the graphic design of the separate "screens" presenting a basic element in the process of human-computer interactive interaction. The development of computers, and personal computers in particular, the extension of their possibilities to work in the graphic mode, eliminates the difference between artistic design by means of paper, pencil and coloured pencils and design with the assistance of specialised computer packages of applied programs for information visualisation.

The computer offers something more - while in the classic visualisation of information it is impossible to apply the animation approach with computers as a result of their quick operation and the consecutive deposit of images perceived by the human eye as a continuos alteration of the image we gain a number of additional possibilities for visual impact.

Advantages and disadvantages of visualisation in education and training

To be able to use visualisation to its maximum potential we need to understand what characteristics of visualisation cause it to be advantageous. In this way we can better estimate when visualisation will be the most beneficial.

Psychological and instructional aspects

The acceptance of individual differences leads to three possible approaches. The first approach is to make understanding as easy as possible for each individual by supporting both text and visual modes of presentation. The second approach is to present only the mode that best fits the individual student. Thirdly one can argue that everyone should be proficient in reading both text and visuals, so making it too simple would not stimulate the reader/viewer to train his abilities. We guess the solution to this dilemma lies in the nature of the instruction. The question whether or not to teach visual literacy is strongly related to questions of teaching common knowledge, it does not explicitly belong in the school curriculum but it is expected from good general education. Training and reschooling of adults has less general and more specific goals and the designer of learning materials in this area may therefore try to optimise learning outcome by neglecting such goals as visual literacy and optimise the learning by teaching in the mode most suited for the individual learner.

A disadvantage of visualisation of the learning content is that many times the link between the symbol and its meaning are more or less arbitrary, based on associations of the mind.

Because of individual differences one can never be certain someone else will have the same associative link and will therefore be able to correctly interpret the symbols used. On the other hand comprehension can be facilitated by adding context to the symbols. A lonely "trash can" icon on a computer screen could mean many things (time to put your garbage can on the sidewalk, what you have just typed is trash, etc.), adding it to the rest of the desktop concept (icons for disks and files, the windows and menus) could easily lead to the conclusion that the trash can can be used to throw away files and discs.

Several instructional theories focus on the dilemma of either working from abstract to concrete or the opposite. Romiszowski (1981) describes for instance Bruner's classification of three levels of representation; -- inactive, iconic and symbolic, advancing from concrete to abstract (p. 173) -- and Landa's concern about the rule/example sequence (RUL-EG vs. EG-RUL) (p. 179). Examples are usually used to present information realistically, but text is an abstraction itself. To make the best use of examples they should be as realistic as possible. An obvious way to do this is to make use of visualisation. Metaphors are used when a topic has no intrinsic realism. To make the topic more accessible an analogy is found between the topic and a less abstract phenomenon. The metaphor may be visualised and therefore given more realism. In terms of Bruner this will enable students to gain iconic experience with symbolic topics. Direct manipulation (Shneiderman, 1990) of abstract information is possible by visualisation of the metaphor. A major difference between text and visuals from a psychological point of view is the difference between the sequential nature of text and the parallel nature of visuals. For text a predefined direction of processing the chain of characters and words makes it a sequential mode of presentation. For visuals there is no predefined direction of reading, therefore it is possible to display simple items in such a way that it is easy to view the items 'at the same time'.
The motivational aspect of visualisation is clear (Keller, 1983). Programs that look nice are fun to work with. Of course one runs the risk of distracting and therefore decreasing the learning effects, but in general the more motivated the learner is the better he learns. Although motivation from the niceness of visuals is extrinsic, and less beneficial than intrinsic motivation, the general attitudes towards the learning task, towards the program and towards computers are positively influenced by such feelings as the comfort of working with the program and the perceived locus of control (Hartley & Lovell, 1984).

Cross-cultural aspects

Since the beginning of written language people have realised that communication using the arbitrary rules of language is not equally understandable for all. The chance of not understanding the associative relations between symbol and meaning increases when cultural differences between sender and receiver become larger. In general one can say that the less assumptions are made about the rules of communication, the greater the probability of understanding. Communication by text requires language, and language is from this point of view nothing less than an enormous amount of communication rules. By using text the sender assumes the receiver will be aware of these rules and will know how to apply them (quickly enough) to process the message. Language is part of culture; therefore often cross-language will also mean cross-cultural. Cross-cultural communication by text is therefore a problem unless sender and receiver can agree to use one set of rules (one language), provided they possess knowledge of a common set of rules (speak a common language).

Pictograms are iconic symbols. Using graphical representations one can create an icon language, which is again a set of rules, but the associative link between symbol and meaning should make the icon language more culturally independent than text. Examples are the pictographic language for traffic regulations or the icon language for organisational and functional focusing of areas and facilities in communication and meeting environments (airports, railway stations, conference centres, etc.). The discussion by Ossner (1988, pp. 8-11) follows the same lines of reasoning and reaches the same conclusions.
To increase the portability and effectiveness of educational software we have to investigate and to apply the full range of cross-cultural advantages of using visualisation (Lanzing, 1991). All these advantages have to be transformed into practical principles and guidelines for software engineers and instructional designers involved in the development and implementation of educational software.
There is however one less positive remark about the advantages of visualisation. The possibilities of visuals to express verbal information detailed enough to communicate whatever you would want to communicate are limited.
What we have been trying to communicate using pictograms has so far been relatively easy to say; "go there", "exit over here", "no smoking allowed", etc To express more complicated things using graphical communication might not make understanding easier, but at least everybody is equally unfamiliar with the symbols used, which could by itself increase mutual understanding.

Technical aspects
Every computer is well equipped to display characters, but only a few of them offer enough built-in aids to make the programming of an interactive system on a graphical screen easy. Also the absence of one standard graphics adapter requires the programmer of graphical software to invest great efforts to make the courseware run on most computers. To overcome this problem one needs to use either an authoring system which supports graphical interaction or a library with adequate graphical functions or objects.
Without the right tools the development of a program that uses visualisation will take considerably more time and effort and therefore more financial means. Depending on the goals, the available tools and experience using them, the difference between the production of courseware in text and in graphical mode will decrease. In the end it might even become cheaper to produce graphical courseware due to improved authoring tools.
The most important limitation of the design of graphical software is the skill needed to produce acceptable graphics. To guarantee an acceptable standard of graphical design one really needs a professional graphical designer to make it look professional. No student can be fooled to work with courseware that looks amateuristic; however good the concept, the instructional design and programming may be, users look at the screen and if they see amateur graphics they will not be confident about the quality of the rest of the program. Of course this will significantly increase the costs of courseware production.
Several techniques for visualisation in courseware engineering are at our disposal. Multimedia techniques combine the advantages of normal video (quality moving images, good production methods) with the interactivity of computers. But the application of these methods still require special devices, installed both with the designer and the user of the courseware. This causes investments which are presently too high for most educational institutions.
Commercial organisations are more and more using such multimedia techniques for company training, where the costs of such techniques are low compared to personnel

costs. This increased usage will probab' iuse the prices of technical support for visualisation to decrease a little, but we still not very optimistic of the chances of the technology for handling these techniques being afforded in schools in the near future.

Graphical techniques use the computer to display either prepared images stored on a computer-readable external medium or images instantly generated by the computer. Because it requires no extra equipment, these digital approaches are usually the cheaper techniques. Therefore these techniques will be used more often. But apart from these economical aspects, digital graphical methods for visualisation are also superior in versatility. Since the image is fully digital the computer can do all sorts of things with it, ranging from adding arrows and marks to image processing.
For a long time the quality of computer graphics has been rather poor and with a low degree of realism, due to both display technology and to the difficulty and labour intensiveness of entering pictures into the computer. The use of scanning techniques has increased the quality of the visuals. The only remaining limitations are the amount of memory necessary for the storage of the images and the speed with which the huge amounts of image data can be processed to produce realistic moving images.
Digitalisation of video, compression techniques and increased graphical resolution and colour will make the gap between the appearance and presumably the effect of both methods smaller. It now seems obvious that the trend towards digitisation of all kinds of information will also progress towards the digitisation of video. Several attempts in this direction, such as DVI and Apple's QuickTime, have been undertaken and may prove to be practical enough to become popular.

Economical aspects
Visualisation always increases the costs for the courseware development. A reasonable problem, not solved until now, is to find the cost-effectiveness point of satisfaction taking the important advantages and disadvantages, described above, into consideration. The solution of this problem is difficult not only because, one cannot estimate exactly the direct and the indirect costs of courseware visualisation at the beginning of the development process, but mainly because till now there is no reliable model to convert the qualitative measured effect from interactive visual-supported courseware into quantitative (and special monetary) figures, for comparison with the rough estimated costs.
The economic aspect is connected with the aspects mentioned above, especially with the cross-cultural one through the portability problem which influences implementation. From the other side, the technical aspects are connected with the costs of software development and therefore indirectly with the level of visualisation.
All the aspects therefore are related and so to study the main research problems a systems approach should be used.

Application of visualisation in courseware engineering

Two directions of visualisation in courseware engineering can be distinguished. The first and most obvious is the visualisation in courseware itself, to improve the learning process. The second is the usage of graphical representation, for instance in authoring tools, to improve the courseware engineering process.

Visualisation for learning

The advantages mentioned before indicate the value of visualisation for learning. Many visualisation techniques are useful, both from the domain of multimedia and graphical methods of visualisation. The effort required to implement visualisation in courseware will depend largely on the development system used, but also on the availability of scanning hardware and on the capabilities of the development team in producing quality visuals or on the availability of legally usable visual materials.

Depending on the learning content of the courseware, the visualisation can serve several functions. Molitor, Ballstaedt and Mandl (1989) offer a useful classification of these functions:

- Representation. The representational function serves to transmit information, usually redundant with text. The use of the representational function of visuals depends largely on the instructional content because it has to be concrete, visible. While a verbal description of the face of a persons may be detailed enough to serve the educational purposes, it cannot be denied that a picture of a face is much easier to interpret and remember.
- Organisation. The organisational function provides an overview or macro structure of the text content. This way the visualisation will probably have the advantages of the advance organiser, but with the extra advantage that it can easily be referenced. Knowledge navigation is one of the major problems in the educational use of large databases such as hyper documents used in discovery-type learning packages. The provided overview of the macro structure may also serve as a kind of navigation tool.
- Interpretation. The interpretation function helps the reader to understand parts of the text, for instance by visual analogies and metaphors. An example of an interpretational use of visuals is the depiction of sets using Venn-diagrams or the use of histograms to show the development of the value of a variable over time.
- Transformation. The transformation function enhances memorisation by providing the learner with extra associative links. The keyword technique (Pressley, Levin, & Delaney, 1982) makes use of this function of visualisation.
- Decoration. The last function, decoration, is used to beautify the text.

The decorative function is not much appreciated by Molitor, Ballstaedt and Mandl (1989), because it can produce negative effects. We think the decoration function itself increases motivation and will therefore produce a positive effect, if not overdone. But we agree that an illustration serving only a decorative function will probably distract because the student will start to wonder about the educational value of the illustration and will spend his time trying to find out the deeper meaning. This categorisation of visualisation functions should not be confused with a categorisation of visuals, in which case one could talk about a decorative picture.

Visual aids for courseware engineering

Advocates of authoring and visual programming systems often claim that "non-programmers" should be able to develop their own software. However we do not consider programming by teachers who are not proficient in programming a good approach. The effort required to make good educational software is much too large to fit within the frame of lesson preparation. We do recognise the desire of teachers to influence the instruction delivered by courseware products. Adaptability of courseware will become more and more important over time when teachers start to integrate courseware in their normal curriculum. As with ordinary school-books, teachers will want to make additions after some years of usage.

Visualisation techniques may help to build systems, that enable teachers to make minor changes to existing courseware, such as removing a paragraph or adding one, replacing a picture, etc.
Other types of courseware, like simulation, modelling and gaming require different characteristics from the authoring system. Modelling systems for instance are programs that allow the user to enter, change and calculate mathematical models. Such programs usually use some kind of visual representation to indicate the transfer of data from one function or block to the next, such as an electrical circuit where the electrical current passes through different components which transform the signal.
Rapid prototyping tools have become increasingly popular in recent years. Rapid prototyping tools are systems that allow experienced programmers to make a mock-up version of software to be developed to discuss about and test the program before it's actually being programmed, usually in some higher programming language. The role of visualisation for rapid prototyping tools is obvious, because the major function of such tools is to produce programs that look like how the final version of the courseware under development should look like. It should give all the people involved in the courseware development process an idea of the functioning of the graphical user interface and the educational interaction.

References

Alesandrini, K.L. (1987). Computer graphics in learning and instruction. In H.A. Houghton & D.M. Willows (EDs.) The Psychology of Illustration, 2 (Instructional Issues), pp. 159-188. New York: Springer

Cole, M. & Scribner, S. (1974). Culture and thought: a psychological introduction. New York: Wiley.

Dwyer, F.M. (1971). A study of the relative effectiveness of varied visual illustrations. Educational Technology Publications.

Einstein, Albert.(1952) "Letter to Jacques Hadamard." In "The creative Process. New York, New American Library, pp. 43-44.

Fleming, Malcolm and Levie, Howard.(1978) Instructional message design. Educational Technology Publications, Inc., Englewood Cliffs, New Jersey.

Hartley, J.R., & Lovell, K. (1984). The psychological principles underlying the design of computer-based instructional systems. In D.F. Walker & R.D. Hess (Eds.), Instructional Software: Principles and perspectives for design and use (pp. 38-56). Belmont, CA: Wadsworth.

Keller, J.M., Development and use of the ARCS model of motivational design 49832. University of Twente, Enschede.

Koenig, J., Bryant, R., e.a. (1991). HyperCASE: The visual application development system [computer program manual]. Toronto: Interactive Image Technologies.

Lanzing, J.W.A. (1991). Visual aspects of the cultural portability of educational software (unpublished doctoral literature survey). Enschede: University of Twente.

Molitor, S., Ballstaedt, S.P., & Mandl, H. (1989). Problems in knowledge acquisition from text and pictures. In H. Mandl & J.R. Levin (Eds.), Advances in psychology: Vol. 58. Knowledge acquisition from text and pictures (pp. 3-36). Amsterdam: North-Holland.

Ossner, J. (1988). Transnational symbols: The role of pictograms and models in the learning process. Pre-DELTA Project TF III task e (paper 5).
Pressley, M., Levin, J.R., & Delaney, H.D. (1982). The mnemonic keyword method. Review of Educational Research, 52(1), 61-91.
Romiszowski, A.J. (1981). Designing instructional systems: Decision making in course planning and curriculum design. New York: Kogan Page.
Rivlin, Ch., Lewis, R. & Cooper, R.D. (Eds.) (1990). Guidelines for screen design. Blackwell Scientific Publications. Cambridge: The University Press.
Shu, N.C. (1988). Visual programming. New York: Van Nostrand Reinhold.
Simonson, M.R. & Hargrave, C. (Eds.) (1991). Proceedings of the 13 annual AECT conference. (IA): Iowa State University.
Stanchev, I. (1990). Software engineering for portability. Journal of Research on Computing in Education, 23(2), pp. 204-224.
Stanchev, I. (1991). Visual presentation of information and design of interactive screens, proceedings of the IV East-West seminar on education technology, Prague, 1991.
Stillings, N.A., Feinstein, M.H., Garfield, L.J., Rissland, E.L., Rosenbaum, D.A., Weisler, S.A. & Baker-Ward, L. (1987). Cognitive science: an introduction. Cambridge (MA): MIT.
Tyre, T. (October, 1989). Authoring packages continue to mature. Technological Horizons in Education Journal, 17(3), 10-18.