Design as Tool for Cognitive Metabolism:
From Knowledge Production to Knowledge Presentation

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Abstract
The use of digital media for knowledge presentation in education and
business (knowledge management) raises two fundamental questions:
the relation between design and cognition, and the role of the still to
be invented rhetoric of audiovisualistics —the combined use of re-
sources from different domains: sound, music, voice, type movement
(animation), and images. The question is addressed of how design can
help to reduce cognitive complexity and make transparent complex
"Sachverhalte". The claim is made that a research policy should not
exclusively aim at knowledge production, but take into account also the
process of knowledge distribution and knowledge assimilation. In these
two phases of knowledge socialisation design can assume a decisive role
by structuring and presenting knowledge in such a way that it can be
effectively absorbed making use of audiovisual resources – including
aesthetics as constitutive domain and not simply as a add-on to usabil-
ity. An example of software development for medical education is used
to ground the claim that design plays a catalytic role in the process of
cognitive metabolism.

Data, information, knowledge
In the discourse on information technology and information design
there exists a "progressivist linguistic chain —from 'mere data' to
'processed data' (information) to 'verified information' (knowledge) to,
perhaps, 'existentially validated information' (wisdom?)." (1) Though
alerts have been voiced against a hidden ethnocentric bias behind this
chain, I use the constellation of these four notions as a starting point
in order to address the role that design can play in this process. In

other words, I want to give tentative answers to the question of how design is involved in this chain when data are transformed into information and when information is transformed into knowledge. The title of this text contains a claim for the crucial cognitive role of design for everyday life, learning and management —a role that has become more evident with the expansion of information technology. Through arguments and evidence I shall ground this claim. On this occasion I don't touch the final philosophical question of the fourth level of how knowledge is transformed into wisdom.

The background for my exposition is provided by writings from various sources ranging from those who address the role of knowledge, and knowledge management in organizations, to those who deal with the role of visualization in Enlightenment and the transition from verbal to visual culture. I am pursuing an eclectic strategy for outlining the contour of the issue of design in relation to cognition —an issue that draws on the contributions of disciplines like history, anthropology, computer sciences and cognitive psychology, to name but a few.

A simple example serves to illustrate the process of transforming data into information and information into useful knowledge. Time tables are characterized as lists of data. These raw —and that means disordered— data about train numbers, departure times, arrival times, routes etc. become information when they are structured, that is when they pass from a state of high entropy to a state of low entropy. Already here design intervenes by presenting data so that they can be perceived and received. Once information is organized it needs to be assimilated by an interpreter who knows what train connections are and —moreover— who is in a situation in which these informations address a certain concern. The next step of transforming these bits of informations into knowledge occurs when a user internalizes, interprets and uses the information, that is, translates information into action. It should be evident that the way data and information are presented is of crucial importance for enhancing, understanding and facilitating effective action.

In everyday understanding, knowledge is considered a phenomenon rooted in persons (knowledge in the "brain of persons"), that can also be externalized and deposited as text documents in data banks such as libraries. But two authors of management sciences go one step further and offer the following characterization: "Knowledge is a fluid mix of framed experiences, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organizations, it often becomes embedded not only in documents or repositories but also in organizational routines, processes, practices, and norms." (2)

Though I have certain reservations against this definition of knowledge as mainly instrumental or operational knowledge —leaving aside the hermeneutical dimension—, it brings into focus another feature that touches on design: knowledge as accumulated experience needs to be communicated and shared between individuals. The process of commu-

nicating and sharing knowledge is linked to the presentation of knowledge —and the presentation of knowledge is —or could become— a central issue of design. At first sight it may not be obvious – or simply taken for granted – , that the presentation of knowledge requires the intervention of design actions (*Entwurfshandlungen*); but without design interventions knowledge presentation and communication would simply not work, because knowledge needs to be mediated by an interface so that it can be perceived and assimilated. Otherwise knowledge would remain abstract and could neither be accessed nor be experienced. Here is offered a leverage point for information design as indispensable domain and tool in the process of communicating and at the same time disclosing knowledge. Furthermore, the domain of information design is linked to the domain of education and learning —and, as R.S. Wurman put it, learning and the design of learning— may become a major business in the next century (R.S. Wurman 1999). That is good news. But the bad news is that so far we don't have a coherent theory about information: "Today, in the Information Age, we are struggling to understand information. We are in the same position as Iron Age Man trying to understand iron. There is this stuff called information, and we have become extremely skilled at acquiring and processing it. But we are unable to say what it is because we don't have an underlying scientific theory upon which to base an acceptable definition." (3)

Interaction
Though we don't have yet an unequivocal and differentiated definition of 'information', we have however a professional practice of information design in which contributions from cognitive psychology, linguistics, theory of perception, learning theory, theory of signs (semiotics) and last no least visual design are integrated. In a recent publication about visualization we find the following definition of information design as "design of external representations to amplify cognition." (4) Visualisation is understood as a domain of computer-based interactive representations. One can go one step further and say that visualisation means the transformation of generally invisible processes with the objective to facilitate and enhance understanding.

The various scientific fields that I have listed are grouped around the fundamental concept of communication, that has been enriched with new possibilities by technological development: I refer to interactive digital media. Interactive presentation of information is the challenge that traditional graphic design and other research-based disciplines are facing today. Obviously, even a book is an interactive intellectual tool whose convenience has been proven during centuries, but interaction in the more restricted sense today refers to the presentation of information through digital documents in form interactive media.

I am aware of the dangerous appeal of buzz-words —and 'interaction' is one of them. But I am using the term in a prosaic way. Interaction refers to a manner of presenting information to a community of users in a non-linear way, i.e. as hypertext or information in form of branched structures composed of semantic nodes with choices for the user to move through this net of nodes. Here presentation taps the resources of

different perceptual channels and enables new ways for presenting information, which allows selective access and a simulated dialogue format particularly scientific information that so far has been predominantly text- or print-based using static resources (typography and illustrations).

Dealing successfully with these multichannel aspects —sound, music, voice, type, images, film, motion— requires different competencies or "literacies" that are brought together in teams composed of so-called content providers (i.e. persons with factual knowledge about the domain in question), representatives from cognitive psychology, specialists from music and sound design, illustration, programming, writing and interaction design.

Usability from a design perspective
Taking the team approach as starting point for the development of digital documents and tools, we can ask how to characterize the professional responsibility of the designer in digital media. Looking at the numerous, sometimes conflicting, interpretations of design and its difference from engineering and sciences, we can perceive a set of basic features or constants. I shall focus on only two. On the one side, we have the concern for the user, and on the other side we have aesthetic quality. It is the focus on the user and her/his concerns from an integrative perspective that characterizes the design approach. In that aspect it differs from other disciplines (including ergonomics and cognitive sciences); furthermore a comprehensive design approach does not put aesthetics into quarantine, but explicitly addresses the concern for aesthetic quality, including the dimension of play. At this point we enter a contentious area, because the domain of usability is strongly claimed by well-known representatives of cognitive sciences that deal with web design and carry the banner of usability engineering methods. In order to formulate this exclusive claim on the domain of usability, a rather narrow vision of the world of web design emerges. "There are essentially two basic approaches to design: the artistic ideal of expressing yourself and the engineering ideal of solving a problem for a customer." (5) In this dichotomy between art and engineering, between a self-centred focus and a client-centred focus design does not even enter into consideration; it is simply swallowed up by usability engineering. Design vaporises into the status of a nonentity and designers´ expertise is usually dismissed as irrelevant to the process.

We may speculate about the reasons why this has happened. Perhaps it is caused by an understandable and justified reaction against "cool" pages that are user-hostile though aesthetically captivating —the so-called sexy pages or killer sites. But that is hardly an issue, whereas an uncritical interpretation of usability is at stake that takes this complex notion for granted. Usability appears to be limited to what usability engineers can measure. No designer would deny the necessity of experimental testing of designs, but an understanding of usability that excludes the aesthetic, qualitative dimension becomes a blind victim of aesthetic choices that occur anyway. By a process of self censorship a constitutive aspect of use and daily experience in handling digital

artefacts is excluded. This approach undermines its own relevance and usefulness for assessing web design projects. Concerns for formal quality cannot be disqualified as glitzy stuff and pushed under the carpet only because they are difficult to assess —they probably fall through the rough grid of usability engineering criteria. The claim that "the way you get *appropriate* design ideas (and not just good ideas for cool designs that nobody can use) is to watch users and see what they like, what they find easy, and where they stumble" (6) is anything but new —it is what designers do anyway in their profession. Furthermore, it does not explain how *appropriate* innovations in design occur —it is constitutively conservative and anti-dynamic. Having split up the world into two opposite domains —explaining away design— innovative solutions are explained by referring to the *deus ex machina* in form of 'inspiration' and 'creativity'.

My final criticism is directed towards the unilateral interest in, for instance, the speed of finding an information on a web site, because it overshadows the central issue that the design of interactive media serves to communicate and to enhance understanding. Of course, fast access to information is a desideratum, and slow sites with excess of graphical components and distracting animations are a nuisance, but speed is not an absolute goal. Effective communication however is. And this would include notions of hierarchy, structure, and what may be called "sensory management", the expert choice of stimuli which guide readers and hold audiences captive and attentive.

Audiovisualistics
Effective communication depends on the use of resources that are intrinsically connected with aesthetics. They can be grouped under the heading of rhetoric —of course a revised and modernised rhetoric that reflects technological innovations. In classical understanding, grammar was concerned with formulating texts (speeches) in conformity with rules or formalised conventions, whereas rhetoric was concerned with embellishment *(ornatus)* and the reduction of *taedium*, i.e. rhetoric as tool box for avoiding boredom, keeping the attention and maintaining the curiosity of the audience.

A characterization of the role of the designers who design information, could state that their contribution consists in reducing cognitive complexity, in producing clarity, in contributing to transparency and understanding. This is achieved amongst others by judicious application of resources of visual rhetoric, or, as I prefer to call it: audio-visualistics.

From knowledge production to knowledge distribution
Before presenting and commenting a case history that shows the role of design as cognitive tool or as intellectual technology I want to present a quote from a specialist of literary studies who makes – according to my view – a bold proposal. We all have heard *ad nauseam* the lamentations about information overflow, information anxiety, information explosion, information saturation in our so-called information age and

knowledge-based economies. But I will not indulge either in euphoric mantras of CR (computer revolution) nor in the opposite of information dys-topists. The author writes: "... I am proposing that the great intellectual challenge of this Age of Information is not coming up with a grand unified theory in physics, or discovering the origins of human life. The great challenge is to be better served by what we already *know*." (Emphasis in the original) (7).

Let me explain why I consider this proposal to be a bold proposal and why I consider it particularly relevant for design. It readdresses the priorities of scientific research. Scientists know —and perhaps suffer from— the career-enhancing rite of publishing. Though nobody would object to the production of new knowledge —and that is the main task of the sciences and scientific research— it should be kept in mind that this rite has also its negative side effects. The different domains of knowledge escape any attempt to keep more or less up-to-date. For instance, Harvard University is cataloguing its subscriptions to more than 90,000 periodicals. Historians now have some 5,000 journals to carry and inform their work. Therefore, rather than investing huge resources unilaterally to produce new knowledge at an ever-increasing rate, we might redirect some resources to make existing knowledge available. Richard Rorty is quite explicit about that and recommends: "...that sociologists and psychologists might stop asking themselves whether they are following rigorous scientific procedures and start asking themselves whether they have any suggestions to make to their fellow citizens about how our lives, or our institutions, should be changed." (8)

Exactly at this point designers ought to step in, because they have —or are supposed to have— expertise in reducing cognitive complexity and help to present information by designing the interface between the information source, the data and the reader. This new creed of designers runs under different labels like information architects (a term that I consider misleading, because it is static) or knowledge engineers (a term that I consider even more misleading with its macho-style conno-tations). I prefer the term 'information design' that is the preferred term in continental discourse. Its objective is to facilitate cognitive metabolism, i.e. the assimilation of knowledge.

Designers are not known for producing new knowledge —though there are exceptions. In general however, knowledge production is not the designer's expertise. But designers can play a significant role in the presentation of knowledge. Information technology offers perspectives that Otto Neurath —considered one of the founding fathers of informa-tion design in the nineteen-twenties could not have dreamed of. Visual or information design can become a decisive discipline to counter the so-called information explosion and to contribute to information management. It could become a discipline of considerable social relevance replacing Graphic Design which has become undermined by technological developments.

Mappings
What are the epistemological and interpretative challenges that designers are facing when they get involved in information design? In order to answer this question I want to make use of another term of central importance for information design: the notions of maps and the activity of mapping. Again I want to quote a concise formulation that clarifies what mapping is about —and what it is not about—: "... the map is perhaps the most sophisticated form yet devised for recording, generating and transmitting knowledge." (9) Maps don't depict a reality —they are not mimetic devices—, but they reveal or disclose a reality. The acts of mapping comprise "visualising, conceptualising, recording, representing and creating spaces graphically." (10) But not only physical spaces, but also and above all information spaces. Design faces here a cognitive task of mapping, for instance, a loosely structured data bank of information in form of texts, sketches, videos, voice recordings, photos, illustrations, diagrams, and animations about a topic in education, onto an interface that can be perceived, understood and acted upon by the final user who wants to learn something. Therefore, the design of information requires first giving structure to a mass of data and then translate these into visual and auditive formats with netlike pattern for navigation.

We can differentiate between searching for information and understanding of information. In both cases maps can serve as devices for orientation and penetrating deeper in a knowledge area. Maps serve two different, though mutually dependent purposes: to facilitate access to knowledge and to assimilate knowledge —what I call cognitive metabolism. On the one side, maps provide overviews of data structures and tools for finding, because a surfer is less interested in searching then in finding —we need "find" engines and not "search" engines. On the other hand maps are devices for translating knowledge into an audiovisual space, that is a perceptual —material— space that makes knowledge tangible. It should be obvious that the multichannel resources offered by information technology increase enormously our possibilities for accessing and assimilating knowledge —and of course transmitting knowledge. The traditional procedure for storing and transmitting knowledge are writing and printing. The importance of graphic representation of speech for social development and education and the advantages of literate cultures compared to oral cultures has been brought to attention particularly by Jack Goody (Goody 1987, 2000). But nowadays we have audio-visual —and not only graphic— resources at our disposal. Thus the complexity of knowledge presentation has grown. Handling this complexity is a design issue. Our study programs in primary, secondary and tertiary education are still text-based but will probably in the future be audiovisually-based. I am not advocating the loss of the importance of texts, definitely I don't believe in the end of the book; what I am advocating is design practice and design research in audiovisuality.

A case: software for medical education
In order to reinforce my claim of design as a cognitive tool I shall give a synthesis of one project of information design. I am using this

example to indicate the many competencies the information designer needs to acquire. This project shows the approach, method and contribution of designers for developing material in form of a CD-ROM to be used in courses for students of medicine. The topic is the function of nerve cells, more precisely of cell membranes which are subject to complex chemical and electrical processes. These complex invisible processes, occurring on an atomic level, are difficult to comprehend when relying on texts only with static illustrations. The understanding of these processes is crucial because they explain for instance the reasons why aspirin works.

At the beginning a medical expert prepared a loosely structured data bank with sketches and texts and a general idea of a scenario (sequence in which the material might be organized in linear fashion without interaction). The designers analysed and compared medical text books, collected material from sites, analysed CD-ROMs for education of medical students. Once having themselves acquainted with the subject matter, the designers structured the material in detail, planned animation sequences, sketched illustrations, edited and rewrote all texts for better on-screen readability. A visual system was developed (colour schemes, appropriate type for screen presentations, lines, textures, digital treatment of photographs, types of illustrations, components for animation processes, short movies), that I all audio-visual algorithms.

Illustration 1
Layout structure of the screen.
Top area with chapter, main animation area,
text column right, navigation bar below with
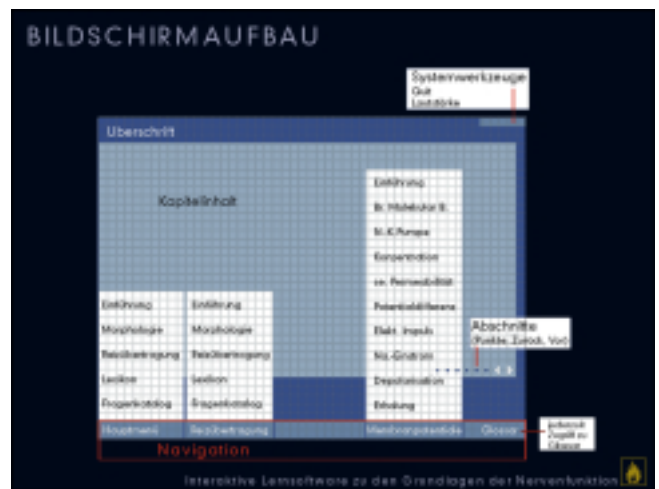*pop-up menus.*

Illustration 2
Examples of the visual grammar for
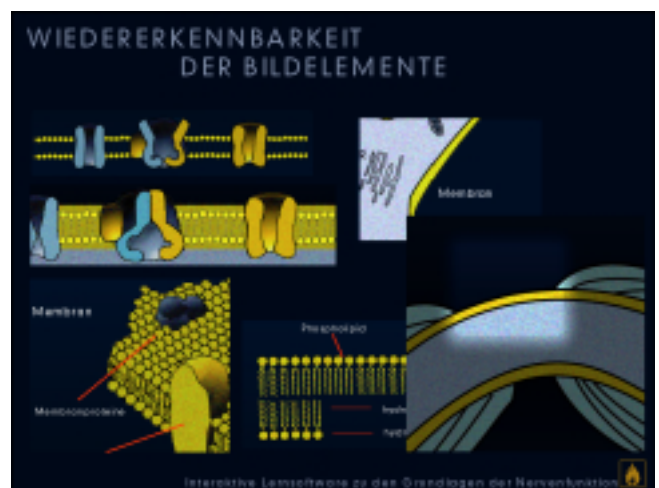*recognizability and visual coherence.*

Illustration 3
Example of a screenshot for an animation of a virtual experiment. Moving the tool with the mouse towards the knee a highlighted impulse is moving along the nerve provoking the muscle to contract.
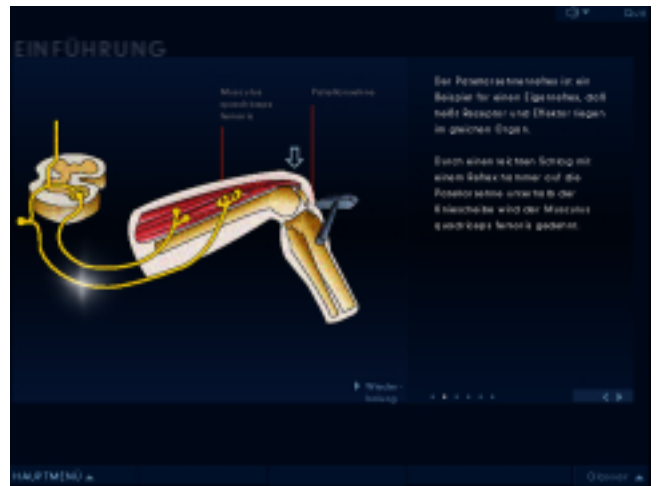

Illustration 4
Screen shot of an animation. Exchange of different ions with positive or negative charge in intracellular and extracellular space through "pumps" in the membrane of the cell.
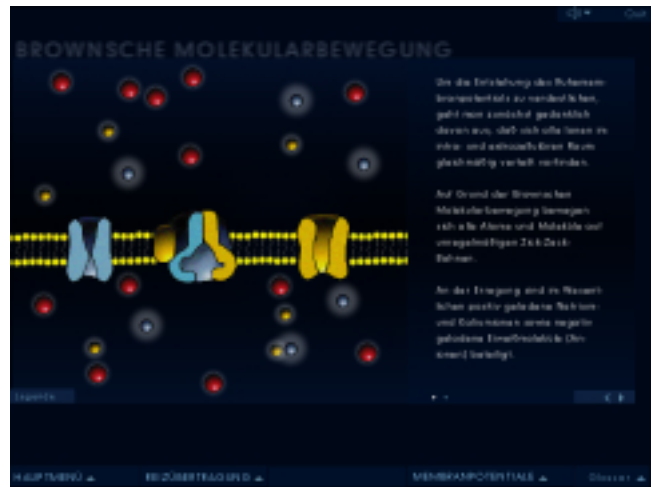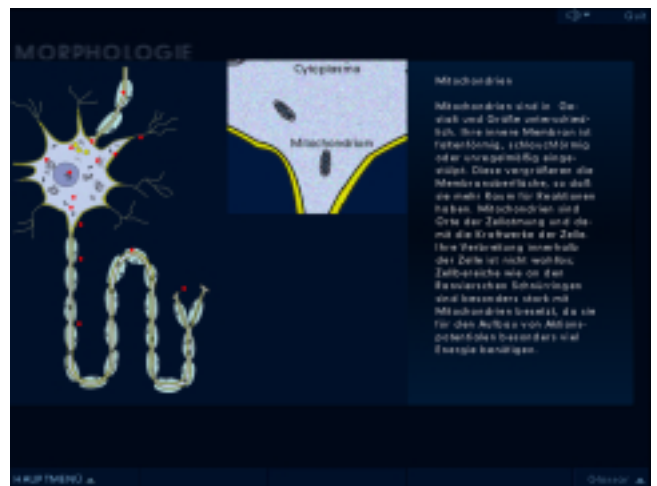

Illustration 5
Example for the use of a "lens". Moving the cursor over the figure on the left, the detail is shown in amplified scale.

Thus organized the data were mapped on to an interface focusing on clear navigation, orientation and hyperlinks. Different animations had to be designed in detail. Video sequences were filmed. Texts were recorded for commentaries, and sometimes needed to be re-written by the content provider —a neurophysiologist— when he discovered that certain issues required more detailed treatment. A glossary of technical terms and a set of exercises for checking the understanding of the material by the medicine students have been added.

At the heart of the project virtual tests were designed which allow the student user to measure electrical potentials inside and outside a model cell and to read the values on a display. A set of exercises has been added to check the medical students´ comprehension of this complex subject matter. To this, a glossary of technical terms was added.

The digitized materials were imported into an animation program, with the corresponding programming. The prototype was tested with medical students to assess degree of acceptance, understanding and quality level of usability. These observations provided essential feedback for an improved second version.

The whole project presented a challenge not only of visualization of complex processes, but of proposing solutions that would enhance understanding and achieve a satisfactory level of visual literacy. It went considerably beyond what is understood as "screen design". It started as an exercise from content, it continued with the transformation of knowledge into some form that could be communicated as shared knowledge. Knowledge has not only to be produced, but it has to be given a form and communicated. The example I presented shows the role of design for the process of knowledge assimilation, and moreover it shows that a successful research policy should not aim exclusively at knowledge production, but should include knowledge communication and knowledge assimilation.

Topics for a design research agenda
I want to finish the tour on design and cognition with a research agenda. Compared with other domains, design is a scandalously under-researched field. I limit myself to mentioning three areas that can provide fertile ground for design research.

1
Design history, in this context of my presentation particularly the history of information design, not understood as a history of heroines and heroes, but as a history of innovations (in the literature about innovations, industrial design and graphic design is hardly considered as a field in which innovations occur apart from marginal aspects related with the form of products).

2
Audio-visualistics
Classical rhetorical and semiotic studies are limited to text and language, that is single media, whereas modern technology offers multimedia, that tap multichannel resources and offer selective access to information. We see a new culture in the making, but our tools for analysing and understanding the design aspects of this new culture are rudimentary and need to be updated. In this way we would build up a wall against the avalanche of "porridge speculations" that go under the heading of mainly rhapsodic and somnambulist speculations about New Media.

3
Knowledge presentation, learning and management
Educational and business software analysed from a design perspective, that would explicitly include the power of audio-visual rhetoric, could lead to a better grounding of design work in this fast expanding field.

These are but a few topics that could be proposed to the institutions responsible for financing research. But in addition to financing we need institution building that facilitates design research —I am afraid that our institutions of higher education are not well prepared to deal with these challenges, because their management structures suffer from hundreds of years of tradition. It is evident that design research can only be done in inter-disciplinary cooperation with participants from different backgrounds. We will probably observe phenomena of 'intellectual migration': scientists moving into the field of design and designers moving into the field of sciences. That is an encouraging perspective.

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Notes

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Illustrations
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Biographical note

GB studied at the Ulm Institute of Design (HfG), in the information design department, and worked at that institution from 1960-1968 in teaching, research and development. 1968-1993 design and consultancy activities in Latin America for multilateral and bilateral international organizations in the area of technical cooperation for industrial development (Chile, Argentina, Brazil). 1987-1989 work as interface designer in a software house in California. 1995-1999 academic coordinator of the master degree course in information design at the University of the Americas, Puebla (Mexico). 1981-1999 Consultant of the National Council for Scientific and Technological Development in Brazil. Since 1993 Faculty member at the University of Applied Sciences, Cologne (Germany), in the area of interface design, with emphasis on: educational software, business software, network presentation of companies and institutions. At present consulting and research work on rhetoric of interactive media, knowledge presentation, and networked learning tools.

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