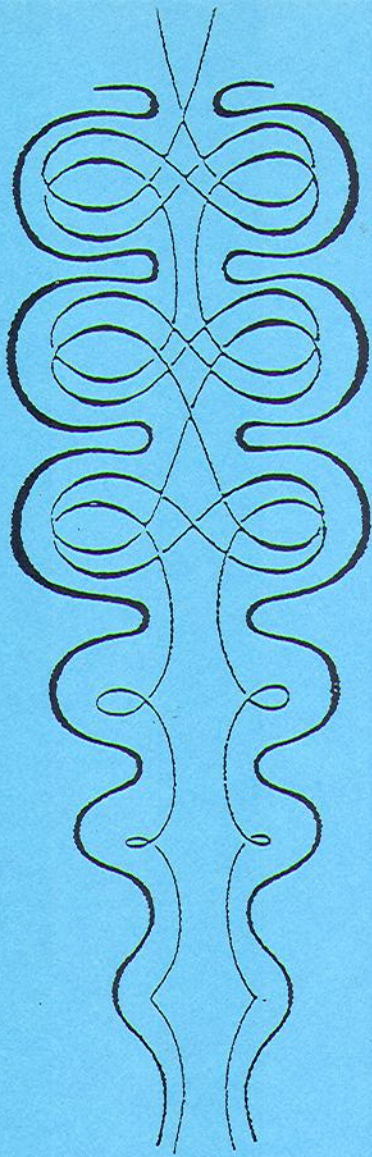


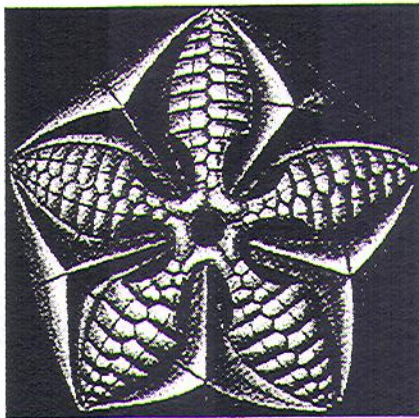


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WALDORF SCIENCE NEWSLETTER

Editors: John Petering & David Mitchell
1158 Quince Ave.
Boulder, CO 80504
FAX 303/541-9244



Book Reviews

It is a real joy when a colleague writes a book that gets rave reviews. The editors have not seen this book by Craig, yet, but we wanted to share what other people have said about it.

— DSM

COMMENTS BY PROMINENT BIOLOGISTS ON GENETICS AND THE MANIPULATION OF LIFE

The Forgotten Factor of Context

by Craig Holdrege

"This essay by Craig Holdrege is for all of us who want to understand the biological revolution of the late 20th century. . . this knowledgeable explanation is the single most accessible source not only of information (on the implications for Homo Sapiens of the esoterica of the new genetics and cell biology) but of knowledge and wisdom."

Lynn Margulis,
University of Massachusetts, Amherst

"In this readable book, Holdrege provides a lovely exposition of living organisms not as objects, but as process, and of heredity as a blending of "potential and plasticity" with "limitations and specificity!" With a wealth of interesting examples, he shows how genes (DNA) alone cannot "determine" traits, much less organisms, because their effects are always qualified by the contexts within which the organisms live. He thus offers an antidote to the current mechanistic thinking about genes as causes of health, disease, and behaviors. But the special contribution of this book is that it details, simply and again with fascinating examples how scientists' ways of conceptualizing organisms and manipulating them and their parts are at the heart of the formulations they offer about how organisms and their molecules function. The reader can thus observe how

scientific observations and their interpretations fuse in the creation of systems of scientific explanation."

Ruth Hubbard,
Harvard University

"... Deny the importance of context – which is to deny the importance of the evolutionary ecological world view - with the modern molecular synthesis, and we pay. Is it ignorance or complete denial? Reading Craig Holdrege's *Genetics and the Manipulation of Life*, I am tempted to shout that this may be the most essential new book of our time."

Wes Jackson,
The Land Institute, Kansas

"As a geneticist trained in reductionism, I appreciate Holdrege's original book. In our search for universal truths disconnected in time and space, we lose all sense of the context that made the problem interesting in the first place. All budding geneticists, indeed, all biologists, ought to read this important book."

David Suzuki,
The David Suzuki Foundation, Vancouver

One of the major risks of genetic engineering biotechnology has a conceptual basis that Craig Holdrege thoroughly dissects in this fine book.

It stems from scientific reductionism, objectivism, and the mechanomorphizing and reification of genetic and developmental processes. The belief in genetic determinism is as dangerous ethically as it is flawed scientifically because DNA does not contain all the "information" necessary to produce a living being. The antidote that Holdrege offers is in seeking an understanding of relationships via contextual thinking, based in part on regarding heredity as potential or plasticity complemented by heredity as limitation or specificity; and on concern and responsibility for the effects of genetic manipulations on the organism and the environment.

This book should be read by all involved in biotechnology, its advocates critics, and students of the natural sciences.

Dr. Michael W. Fox
Vice President
The Humane Society of the United States and author of
Superpigs and Wonder Corn



Henri Bortoft will be traveling throughout the United States this autumn. What follows is a review of his soon to be released book.

- DSM

The Wholeness Of Nature: Goethe's Way Toward A Science Of Conscious Participation In Nature

By

Henry Bortoft

If I were asked to recommend one book on Goethe's contributions to natural science and philosophy, it would be this book. Bortoft gives a clear and conceptually precise account of Goethe's theories of color and of plant and animal morphology. But what makes this book stand out is that Bortoft does not simply write about Goethe, he shows how Goethe's "phenomenology of nature" can be practiced today. Moreover, through an impressive discussion of perception and cognition that draws from a wide range of sources, Bortoft demonstrates how the Goethean science of qualitative wholeness is a necessary complement to the analytic and causal-explanatory framework of modern science.

Evan Thompson, co-author,
The Embodied Mind

The great merit of this fascinating book is that its author liberates us from our own limited minds. He puts us in touch with one of the finest minds our species has ever produced and reopens vistas long closed off to us by the narrow constrictions of an overly mechanized view of nature.

Edward Oakes' author,
Pattern of Redemption: The Theology of H. U. von Balthasar

This is a gem of a book Bortoft has made Goethe's thinking available in a particularly clear way. He has brought Goethe up to date, showing how relevant his thinking is for a post-quantum world. Goethe's method, in fact, could well point toward a new direction in science – the science of the 21st century.

David Peat, author,
In Search of Nikola Tesla

Henri Bortoft writes out of extensive experience with Goethe's methods of observation. His book bears witness to what a participatory science could mean for the way we see the world and ourselves.

Arthur Zajonc, author,
Catching the Light

Many of us yearn for the maturation of modern science – its transformation from the calculative manipulation of deadened objects to an attentive exploration and participation with living nature. Goethe was one of the

great pioneers of such a science – one which unites our thinking minds with our sensing bodies, and hence with the sensuous earth that we share with the storm clouds and the swallows. Henri Bortoft offers us here, a precise and much needed guide to Goethe's scientific imagination.

David Abram, author,
*The Spell of the Sensuous:
Perception and Language in a
More - Than - Human World.*

* * * * *

Every once in awhile a rare book comes along which contains new thoughts to difficult problems. The following reviewed book by Michael Diamond should be in the library of every Waldorf High School teacher!

-DSM

If You Can Keep It: A Constitutional Road map to Environmental Security

by

Michael Diamond

What follows are reflections by the author about *If You Can Keep It* and how the book came to be written.

Sometimes, if you happen to be in the right place, at just the right time, with your consciousness button set to receive messages, a wider truth can pour into you, whether you are ready or not to deal with it at that moment. Just such a thing happened to me in 1981. The experience has wide ranging implications for education, indeed for the educability of our children and ourselves.

In 1981, I was employed as a chief administrator in a state environmental department, enforcing environmental laws. I was suddenly struck with realization that the laws I was enforcing were not geared to protecting our general health. Those laws were crafted upon rough calculations as to whether particular chemicals probably caused or did not appear to cause cancer in humans. No thought was given to morbidity in the population as a result of constant and multiple chemical exposures.

In fact, toxin-driven morbidity has been the principal reason for precipitous declines in education since the 1950's, when we geared up to be the major producer and discharger of chemicals on the planet. Toxins have been silent visitors to every classroom and every graduation for over two generations. They have stolen the birthright of bright promise and abundant awareness from our children. The evidence of that theft is all around us, all the time.

The late historian, Barbara Tuchman, said it best in her 1987 article entitled "A Nation in Decline," (New York Times Magazine, Aug. 20, 1987, page 52) when she decried America's "deteriorating ethics, poor performance, poor thinking, and lawlessness," saying that "it does seem that the knowledge of a difference between right and wrong

is absent from our society, as if it had floated away on a shadowy night after the last World War." Barbara Tuchman, a keen observer, had noticed and was writing about our slide, as a people, into barbarity toward a brute society caused by toxins within us at levels wildly beyond our genetic history.

Knowing all this in 1981 drove me to search for a way to require government to devote sufficient resources (human and financial) to deal with this crisis. I kept asking myself how could we be so close to an unspeakable abyss without some legal or political mechanism that would get us to safety and survival. Some five years later, either I found it or it found me. There's no use in being too certain about the sources of insight.

It was right there in plain view all the time--in the Constitution of the United States, created at Philadelphia in 1787. So buried in the sands of misuse was the phrase that can take us to safety and environmental security that it is never discussed publicly. The particular phrase doesn't even appear in the indices to the various books on the Constitution. I think of it as being a time capsule left for us by the framers to help us get out of the environmental crisis we've created for ourselves.

Article IV, Section 4 of the Constitution was, in fact, the most important part of the Constitution. It was the glue that made the Constitutional Convention work to turn out a document that created a federal government with powers adequate to ensure survival in times of crisis. In brief, that Article requires the United States to protect us against "invasion" and against "domestic violence."

What the framers meant by domestic violence was harm that we were likely to do to ourselves in the future, such that survival would be put into question. In the 20th century, we have created a condition of Constitutional domestic violence through environmental harms that we have brought upon ourselves. We are headed toward a brute society on an uninhabitable Earth. Under the Constitution (Article IV, Section 4), the federal government is obligated to put aside all lesser agendas like waste and war and make public health and environmental protection first priorities.

The domestic violence clause is not one to be litigated by lawyers in courts of law. It is a people's clause around which we are to gather together, creating a movement. That movement can change the nature of our economy and the face of our government. IF YOU CAN KEEP IT is a primer that shows us how to go from studying that clause to changing our society, making survival possible.



David Booth from The Green Meadow Waldorf School sent us the following.

-DSM

First Lessons in Astronomy

by
Hermann von Baravalle

Hermann von Baravalle was the last of it's original Waldorf school teacher to remain in active work. He was somehow involved in each of the early North American Waldorf schools besides being a nationally recognized authority in mathematics education. This began even before he left Europe when two visitors came to Stuttgart from New York City to prepare for the opening of Rudolf Steiner School - they were put in von Baravalle's care.

The following are the opening words of a public talk made in the 1960's in Spring Valley, New York from a tape recording of made by Cynthia Schwabenland of Seekonk, Massachusetts. The Science and Mathematics Association for Research and Teaching is making a collection of von Baravalle's popular lectures with the plan of eventually publishing them in a bound volume. These lectures concerned anthroposophy, Waldorf education, mathematics, and science instruction.

Editor: David Booth, Green Meadow Waldorf School
Hungry Hollow Road, Spring Valley, New York, 10977

Looking into space, the nearest object is the moon. We know more about the moon from observation than any other celestial body. Details are known, not just theoretical conceptions. If one of the bigger buildings were to be erected on the moon, it might be visible in telescopes. The facts that can be found about the moon are among the surest in astronomy.

I will write down here 27 days and 7 hours, the time required for the moon to make its orbit around the earth. I will also write down the distance to the moon from the earth: 384,000 kilometers. From this time that is taken and this radius, we can calculate the speed of the moon in its orbit: 1023 meters per second. The data can be found in astronomical books and encyclopedias.

In a number of textbooks you will find this speed compared to that of a bullet. Bullets travel in the neighborhood of 900 meters per second. The numbers invite a comparison: 900 and 1000 are approximately of the same size. So the moon goes around the earth with a speed close to that of a bullet through the air. We could say that to young people.

Well, all right, the data are there; we do not deny that in any way. But we might also do the following thought experiment. The diameter of the moon is 3,480 kilometers. When the moon moves with that same speed, it travels 3,628 kilometers. These numbers are in the same neighborhood. So with these given facts too, we could say that the moon moves through its diameter in one hour. Why don't we transfer that to the mental image of a bullet.

We would have to say that the bullet, about so big, moves through its own diameter in one hour. Compared with a bullet that moves its own diameter in one hour, the moon would not seem quite so quick a messenger.

Now these two ideas can stand side by side; both are correct according to the data that can be found in encyclopedias. It is just as true to say that moon orbits the earth as fast as a bullet shoots through the air, or to say that the moon travels the length of its diameter in one hour.

There you are. I want to illustrate through this comparison, in which both statements are correct, that it makes a great difference in the mind of a young person which one you use. In both cases you left one part out. In the first case you compare with the bullet and leave out the size of it. In the other you compare it with its own size and it resembles a snail more than a bullet. It is slower than a snail.

You can imagine that this comparison that I have taken can be multiplied by hundreds in astronomy. All I wanted to show is that we have to be very careful with our comparisons if we want to avoid a one-sided impression. Another could be placed by its side that would lead almost to the opposite point of view. What should we do? We can have terrible confusion's when we consider cosmic speeds and sizes and compare them with bullets, snails, or anything like that.

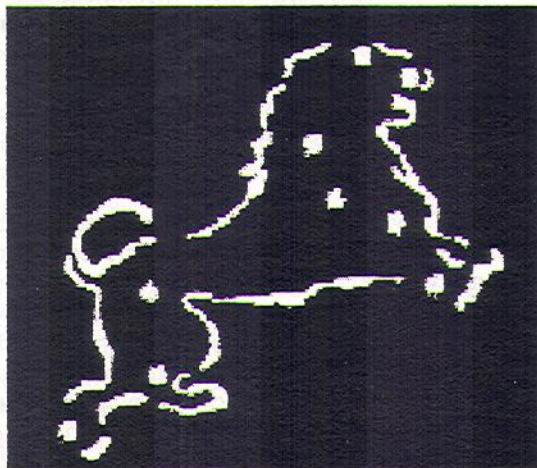
One thing is always safe, to go from these derived ideas, from numbers, from various types of theories, to go back what we see in the sky. Instead of going on with these ideas that come from applied arithmetic, we mentally form the impression of what is seen. This is just about the only way to avoid the dangers that appear by proceeding in the other way.

It has been a great step forward to have demonstrations in the planetarium where we see things from within. Previous models were made so that we stepped into a position outside from which they could never actually be seen.

Well, how do we see the moon in its turning about the earth? The moon always rises and sets in the surroundings of a certain group of stars. Whereas all the other stars go together presenting us with a picture that is sometimes over the Eastern horizon, sometimes in the West. The moon will gradually change its position in the group of stars during the night, whereas all the other stars go together. The moon will not be in the same spot among its group, so to speak. It will gradually change its position. It can be observed during one night, or observe it very definitely from one evening to the next. If we do not want to spend a whole night on that observation, then the simplest thing is to watch it on successive evenings. We see that the moon in moving from the East will fall behind. It will be more to the left.

That is one of the first observations to be made in the night sky. In one day's time the moon will fall behind its star group by a distance of one and a half hand widths

seen at arm's length. That is how far the moon will fall behind its original star group. The moon does not stay at the same place within the star group; measured with our outstretched arm and hand it will be one and a half hand-widths back. That is the change of the moon against its star group. What is the background star group?



I have here pictures showing the stars along with pictorial representations that go far back in history and reappear in various forms from culture to culture. You could hardly get a better picture of a lion with a few white dots on a dark background than this one. See the gesture of it. You also have the Gemini, and Taurus with this one star that is in the middle of the head, with horns, and so on. We could make a study just of how these points of light can artistically fit with a picture in order to awaken the imagination.

It is necessary that you take the trouble to really put these things together. In many atlases we can see that the lion is drawn only in the neighborhood of its stars; the picture hardly fits with the observation. We want to have that star group and its name made familiar by using the right relationships.

The moon will be standing along the edge of one of these twelve pictures. They are always around us. Whenever we see the sky - for instance in the daytime during a total eclipse - half these pictures are above us and half below the horizon. We are really in the middle of the totality of these twelve constellations.

The next day the moon goes a step further, the day after that a step further yet. In 27 days, a month, it will return to the group in which it stood before. Here we have one of these changes that occur in the sky; it is easy to observe, we do not need a telescope; we only require the awareness to look into the sky. Every evening we have the opportunity for these observations - whenever the moon appears above the horizon. If it is not up in the evening, try it in the later part of the night. It is only when the moon has disappeared from the night sky for a few days that we cannot make these observations.

Readers of the Waldorf Science Newsletter who are interested in this topic, the notes of Hermann von Baravalle, or in the application of the phenomenological method in sci-

ence, mathematics, and education, may contact the Science and Mathematics Association at Green Meadow Waldorf School for further information.

* * * * *

The Growing Classroom. Garden-Based Science

(1990; 480 pages; \$27 plus shipping.)

by

Roberta Jaffe & Gary Appel

Reviewed by Larry Lowery

The Growing Classroom is a delightful new book that serves as a resource for garden-based science activities at the elementary level. The book is filled with projects, experiments, investigations, and observations designed for cooperative small group learning. The writing and artwork convey the joy of the enterprise. Funny, alliterate, and clever activity titles will be appreciated by students (*Ear-Ye*, *Ear-Ye* is an activity on the sense of hearing; *Ravishing Radish* examines different micro climates; and *Babes in the Woods* demonstrates the short time humans have been on earth). Unshaded line drawings by Kate Murray show the spirit of fun in doing the activities, convey scientific accuracy where needed, and provide insightful messages to the teacher in order to emphasize an idea.

There is hardly a biological science topic that can't be found within the book's nearly 500 pages of ring bound text (a nice feature because it allows the teacher to lay the book out without the pages closing on themselves). The book is divided into four major parts, each made up of subsections and activities. The first, *Breaking Ground*, helps teachers act started through background information and a philosophy about gardening and teaching. The second, *Science Units*, is filled with a garden of fruitful classroom activities from which the teacher can harvest at will. The third, the *Nutrition Unit*, provides activities that help youngsters investigate food values from both the nutritional and consumer perspectives. The final section rounds out this very complete resource book with blackline masters, addresses for plant and animal resources, planting guides, and curriculum organization plans.

The content of science is thoroughly covered through the activities. *Life Cycles* lets students explore aspects of change. An extensive section titled *Climate* invites youngsters to study the effects of temperature, wind, rain, sleet, hail, and sunlight. A set of activities on *Garden Creatures* introduces animal/plant interrelationships through the study of pesky garden pests that are just trying to make a living. And a section on the important concept of *Interdependence* provides hands-on experiences with the ways in which various life forms are linked and webbed together.

In addition to the extensive and accurately portrayed biological concepts there is a feature that should delight teachers. The beginning activities are designed to introduce youngsters to developing the skills and attitudes of working together cooperatively. Carefully chosen for their contribution to enhancing cooperation across a range of

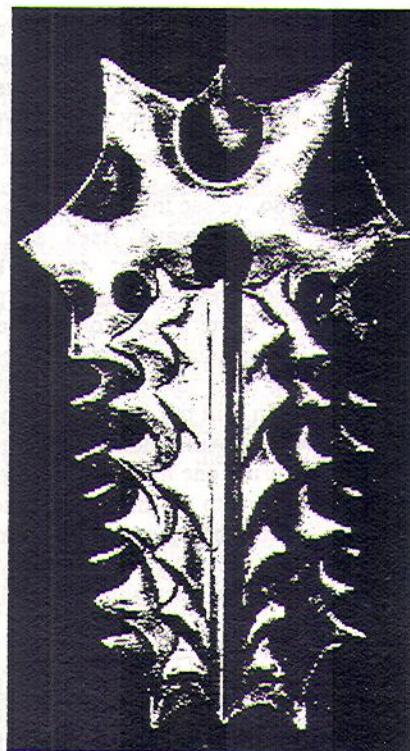
different settings, the teacher will find indoor and outdoor, active and quiet activities. Some emphasize communication skills; others, concentration and listening skills. All involve thinking and problem solving skills that require group efforts in order to resolve them.

The activity titled *Knots*, for example, has youngsters cooperate to solve a physical problem in which their joined hands form a complex set of connections that need to be unraveled without separating hands. The *Sinking Ship* activity challenges groups to work out a plan for survival by considering what items from a limited number of supplies can be taken with them. Each type of cooperative activity in this beginning section reappears in some form among the many science activities that complete the book.

In a broad context, the book exemplifies contemporary thinking about how best to teach science to youngsters (the combined hands-on/ minds-on approach), and it fills a current void in the traditional science curriculum (the learning of biology in a real rather than an expository or laboratory context). In addition, the small group cooperative learning strategies used extensively through all the activities provide important skills and learning values that traditional instruction fails to establish.

For those who love life, gardening, children, and teaching, this is an important book to add to their professional library.

Larry Lowery is a professor at UC Berkeley and Director of the Full Option Science System, a new grade 3-6 hands-on science curriculum being developed at the Lawrence Hall of Science.



LETTERS TO THE EDITORS

The editors received the following announcement from John Barnes.

RENEWAL IN SCIENCE

A publishing impulse in search of sponsors

At a time when our scientific knowledge of the physical world is expanding at an unprecedented rate, there is a growing sensitivity and longing for the spiritual. Increasingly, we can observe within our contemporary culture a polarization of scientific materialism on the one hand, and ungrounded, subjective or fundamentalist spirituality on the other. Meanwhile we are faced with an ecological crisis which reflects our inability to form a deeper relationship with our natural environment.

There is an urgent need today for a scientific approach such as that pioneered by Goethe 200 years ago, a phenomenological, holistic, and participatory approach which comes to see nature, in all its richness, as the concrete manifestation of creative spiritual principles. Rudolf Steiner spoke of Goetheanism as a "medicine" for our world, a "method for a true healing of contemporary humanity." (Nov. 1, 1918)

The goal of Lindisfarne Press's Renewal in Science series is to introduce Goethean science to the interested American public and scientific community. It will publish works of high scientific integrity and make a concerted promotional and marketing effort to reach this broader audience. Its advisory board includes Fred Amrine, Christopher Bamford, Jochen Bockemuhl, Henri Bortoft, Ron Brady, William Brinton, Norman Davidson, Stephen Edelglass, Malcolm Gardner, Craig Holdrege, Ernst-Michael Kranich, Mark Riegner, David Seamon, Wolfgang Schad, Stephen Talbott, and Arthur Zajonc.

This fall the series will publish its first two books

Genetics and the Manipulation of Life

by Craig Holdrege which has won the enthusiastic acclaim of prominent biologists

The Wholeness of Nature:

Goethe's Science of Conscious Participation in Nature

by Henri Bortoft, physicist and student of David Bohm.

These excellent books are sure to spark broad interest. We wish to follow them with four books on evolution.

We are now actively seeking funding for translation from the German of the following works:

FRIEDRICH KIPP, *Die Evolution des Menschen im Hinblick auf seine lange Jugendzeit* (1980) – *Youthfulness and Human Evolution*. In this exemplary work, Kipp shows that extended childhood and youth are a central principle of human evolution through which humanity has

avoided early adaptation and has maintained the inner flexibility to develop new spiritual capacities.

ERNST-MICHAEL KRANICH, *Von der Gewissheit zur Wissenschaft der Evolution/Die Bedeutung von Goethe's Erkenntnismethode für die Evolutionstheorie* (1989) – *From Certainty to the Science of Evolution: The Importance of Goethe's Scientific Method for the Theory of Evolution*. Kranich demonstrates how exact imaginative participation leads to a new and more comprehensive understanding of evolution. He shows how the stepwise evolution of vertebrates from the fishes to the emergence of humanity can be understood as the metamorphosis and increasingly complete manifestation of an archetype as it evolves and adapts to various environments.

WOLFGANG SCHAD, *Aufsätze über Heterochronie und Evolution* (1994) – *Heterochrony and the Dimensions of Time: Essays on Evolution*. In his brilliant interpretation of heterochrony in evolution, Schad points out that the central nervous system consistently plays a conservative role whereas the limbs are active promoters of evolution. The implications of this astonishing discovery are vast.

KARL SNELL, *Schöpfung des Menschen* (1863) – *The Creation of Humanity through Evolution*. Written 133 years ago, this book by Karl Snell is perhaps even more thought provoking today than when it was first published. This first attempt at a scientific understanding of human evolution is breathtaking and utterly refreshing in its radical yet unerring grasp of essential principles. All evolution, Snell writes, proceeds from simpler, unspecialized forms to more adapted and specified ones. He characterizes our evolutionary ancestors as having had the capacity to evolve to higher forms and to become human. Animalness arises when this capacity has been lost completely through adaptation. In his vision of the evolutionary tree, our potentially human ancestors make up the central trunk, whereas the animals evolve on its diverging branches. Animalness arises out of the evolving potential to become human.

In order to begin this important project \$3,000 is needed to translate each of the first three books, which average about 125 pages. Translating the book by Snell, which is 220 pages, will require \$6,000. Actual publication of each work will require between \$5,000 and \$10,000. A gift of \$1,000 has already been made.

Contributions to the Renewal in Science Series can be made to the Anthroposophic Press, R.R.4, Box 94 A-1, Hudson, NY 12534. Telephone: (518)851-2054.

There are many other excellent works in Goethean science awaiting translation from the German. There are also English speaking Goethean scientists whose work needs to be published. For further information, or if you have a suggestion, please write to the Consulting Editor at the address below.

Any questions regarding this project should be directed to John Barnes, Consulting Editor, 320 Route 21C, Ghent, NY 12075; (518) 672-4736.

STEPS IN THE DEVELOPMENT OF THINKING (Power of Judgment)

by
Wilhelm Rauthe

Practical - Theoretical - Ensouled - Individualized Thinking

The following is an attempt to distinguish and describe steps in the development of thinking in the 9th through 12th grades. In many ways, conceptual or pictorial, Rudolf Steiner characterized the development of thinking as the central task of the high school; and one could summarize and integrate these various descriptions in order to come to a picture of what thinking is and how it is developed. However, there is also another possible way. Out of his comprehensive view of this age of youth Rudolf Steiner sketched the curriculum class by class and formed it together with the faculty of the first Waldorf School. The steps in the development of thinking are reflected in the curriculum and can be discerned in it. This is the approach attempted here. As the subjects taught by the author are German and Physics, these subjects will be mainly referred to.

Thinking (the power of judgment) is a complex soul capacity which requires tending in the realms of willing, feeling and thinking. Judgment takes place within the intelligence. Intellectual content and form are both necessary in order to arrive at a judgment. It is this aspect of the power of judgment which will be dealt with here. Rudolf Steiner speaks of it when he stresses that: the right educational relationship with the young person after puberty is "to have him or her next to us in freedom." "Thus one will be able to work from intellect to intellect with this being who has become free."

Puberty brings the breakthrough of the young person's soul into the outer world. "We have seen how the child gradually takes hold of his body, finally of his skeletal system, and how, in doing so, he places himself into the outer world. He must then be able to adapt to the outer world. And this takes place mainly before the 20's." In its mechanical aspect the skeletal system is a part of the mineral world; and the breakthrough leads directly into it. Space is its domain and its laws, as well as the

technology which operates within it, are thus essential to the 9th grade curriculum.

The locomotive – today certainly the automobile engine and the telephone, technological inventions that overcome our limitations in space – is the main thrust in Physics. The spatial view extends as far as grasping the movement of stars in our direction through the Doppler effect. The goal in history is to grasp the character of our own times. The most beautiful picture for this tendency of the curriculum is the goal in Geography, the cross created by the earth's mountain ranges.

Time, however, is also a configuring category at their age. The arts in the various epochs of history and their expression of the spirit of their times also play a role. In history the progression of periods in modern times is studied with a view toward their inner motives, and the spirit of our times should be experienced.

The world in space and time should be penetrated in a practical way and is therefore the object for the development of the practical power of judgment. "Practical" is not meant in the sense of technically correct or technological. True practical activity is dealing with something with understanding, taking into account all of its possible relationships, freeing a part of the world in its interrelationships with the whole. Here natural laws must be seen in their relationship to man, an idea together with its technical application, the invention along with the inventor, the machine with its social consequences. The fourteen or fifteen-year old, who can grasp a machine with enthusiasm and take it up into his warmth of soul, demands this. This means, of course, that all forms of judgment play into this practical one, but they are not developed, not differentiated. And this corresponds exactly with the youthful feelings of this age that life and the world are one great mysterious whole, alluring and frightening.

The telephone and locomotive meet this pedagogical demand as directly as any invention, and they have been dealt with historically in the eighth grade. Therefore the locomotive should not be replaced by the automobile engine. One cannot, of course, teach all the fundamental aspects of electricity, magnetism, heat and mechanics, but only those facts which are necessary to achieve the goals which have been mentioned.

It is through technology that the human spirit grasps and forms the world most visibly. This transformed world and the corresponding social forms work back upon man and become his destiny. This is another sphere of life into which the young person now enters. "... when the child reaches puberty, events effect him in such a way that he experiences them as destiny. It is only by experiencing life in terms of destiny that it becomes for the young person a truly individual life." "... only now can the actions in his environment be viewed as deeds." To relate the world as destiny to one's own I and to see the I of the other through his deeds – that is the other side of practical life and therefore also the realm of practical judgment. Therefore it is also clear that only now the art – the object of which is destiny and which appears as deed – can be experienced: drama. In drama we have an important medicine in which to train practical judgment. In studying Goethe and his time one can introduce his "Goetz." This *Storm and Stress* work brings together all the various spheres of life in which Goetz moved: peasants, knights, noblemen, clergy. It presents us with a full experience of the world. The destiny of the main persons corresponds clearly with their character. The life and death of these persons form a whole; each one dies as he has lived. Indeed, his death is a telling picture of his life.

Today dialectical materialism determines the social views of large parts of the earth's population. Hegel's dialectics, the play of concepts from thesis to antithesis to synthesis, lost its connection with the world of experience and reduced reality to an abstract concept. In their counter-move, Marx and Engels declared the material world to be the only reality and conceptual dialectics became a pure formalism of the intellectual "superstructure." This formalism slipped from the group of the I, and the way it was applied to the world of phenomena became arbitrary. What is necessary is a theory which is "of the essence" (wesentlich), which relates an active I-thinking to the world of phenomena. The capacity to do this shall be called the *theoretical power* of judgment.

This, above all, is established in the tenth grade. In this grade Physics again begins with

mechanics. One takes it "... to the projectile and shows the coincidence of its path with mathematical parabola." Experiments result in two sequences of numbers. These are investigated in pure thought with regard to their relationship and result in the formula for the parabola which coincides with the physical arc of the projectile. The thought process turns away from the observation and finds a law which determines the paths of all projectiles. The young people discover that something which they think wholly within themselves determines as a law all possible cases within a certain field of experience. This awakens wonder and establishes a trust in the theoretical power of judgment. "One must show them that this is something before which a Novalis would kneel in awe," says Rudolf Steiner. It is similar with surveying and crystallography. In the mineral world all possible forms of crystals are determined by the self-contained system of crystallography which can be developed in pure thought.

One must ask oneself why technology with spinning and weaving, technical mechanics and first aid only come in tenth grade and not already in ninth directly after puberty which is the great transition from the second to the third seven-year period. In the ninth grade, in the sphere of practical judgment, the world is still a comprehensive, little-differentiated whole. Therefore Rudolf Steiner suggests for physics teaching "as little theoretical speculation as possible," "... try to develop the necessary concepts through the experiments." In the tenth grade theoretical judgment in pure thinking sets in, creates a tension vis-a-vis the world of percepts and necessitates a strong anchoring in the latter. This is achieved in practical activity which forms a kind of balance to the thinking. The practical activity assures a fullness and variety of observations for theoretical judgment.

The "I", which is not yet independent but still united with the astral body, is called upon when theoretical judgment is exercised. Sureness in the experience of self is achieved. It is as though the dawning of the "I" began to glow. A main theme of the German main lessons comes to meet this: the Edda, Nibelungenlied, Gudrunlied. Out of the heathen, group conscious, blood bound, the individual frees himself in the transition to the Gudrunlied.

The sun-hero Siegfried of the Nibelungenlied is struck down, the Nibelungen treasure is sunk. Mythological themes reverberate and die away. Old Germania and the time of the great migrations are reflected in the world of the knights of the Middle Ages. It is in this world of the knights that Wolfram's Parzival takes place: the work which

forms the central theme of the German main lessons in the eleventh grade. But with Parzival something completely new begins which continues to determine the development of literature up into our time, i.e. in the developmental novel: a striving towards spiritual goals. Human beings move forward on paths of the soul. Parzival strives forward out of naive innocence of soul, through doubt to fullness of spiritual attainment. Each of the main characters has its own personal point of departure and its way to its goal. Throughout its course, the story of Parzival is concerned with inwardness, depth of soul, and thus Parzival is a guide to ensouled judgment which can only find its way in this world and which gains its strength in it.

The new medium of knowledge, the main tool of ensouled judgment, is the pictorial concept. Practical judgment and theoretical thinking are not adequate in the field of inwardness because soul realities are not material, not defined in space, but rather flowing. Wolfram's Parzival is a book of powerful pictures which are not only eagerly received by the capacity of ensouled judgment but also are understood through feeling. Parzival is accompanied from afar on his way to the attainment of the grail by Gawain and Feirafis. For Parzival the attainment of knowledge is decisive, which becomes very evident when he is taught by the hermit Trevrezent in the cave in winter. Gawain is the hero of feeling who, "sad today, joyful tomorrow," achieves his deed of redemption by bearing the powers of antipathy and conquering powers of sympathy and thus liberating the four hundred women in the castle of Schastelmarveil. The heathen Feirafis goes the way of the will. Parzival fights the hardest battles with his friend Gawain and his half-brother Feirafis and in doing so is able to identify himself with them. The "I" in its varied life in thinking, feeling and willing takes on shape in these three main personages. And the lands and kingdoms are realms of the soul. The whole range of soul life appears in numerous positive and negative details.

An excellent medium in which to call upon ensouled judgment is also the metaphor of modern lyric poetry. There habitual realms of soul are transcended and wholly new feelings are expressed and called forth.

In the natural sciences of the eleventh grade pictorial concepts also play a decisive role. Thus, for example, the element sulfur is studied as the end product of the sulfur process which takes place within the earth and within organic protein. "In botany, an understanding is stressed above all of the plant in its relation to the soil in which it grows and

to the effects of the whole cosmos." "But how can one hope to find a relationship between the formation of the plant and the movements of the planets?" ask Ernst-Michael Crunch. And he answers: "We will not find any relationship of an outer causal nature, that is in the sense of the concepts of physics. But there is another form in which relationships and connections express themselves. We will call this the similarity of pictures." In connection with planets we cannot speak directly of inwardness, but the realm of the planets which forms and rhythmizes growth does correspond to inwardness of soul.

Even in the physics of eleventh grade, we deal with "inwardness." Electricity is the power which holds matter together, the inwardness of matter, which never appears and which, when we tear it out of matter, gives rise to other appearing forces. Because it is, as such, absolutely inaccessible to our observation, there is only one faculty which can approach it: pure thinking. And exact consideration demonstrates that it is not as in mechanics or optics, for example, where laws are deduced from what appears to the senses, but that the essential features of electricity are reduced through thought alone to pictures, to the circuit symbols, and that these are filled with conducting materials in electrical appliances. In this way, ensouled judgment can be established in great breadth in the eleventh grade by developing the corresponding pictorial concepts in connection with the inwardness of man and the world.

In the *Pedagogical Youth Course*, Rudolf Steiner draws our attention to the following: ". . . before a point in life which lies between the eighteenth and nineteenth year approximately, one cannot know anything which requires judgment gained through active thinking. Just as little as one is able to get one's second teeth before the seventh year, can one before one's eighteenth year really know something about questions of life which lie beyond one's immediate grasp, above all, about things which require active judgment. Before one's eighteenth year, one cannot unfold the inner soul activity which is necessary in order to be able to say: I know something about this or that which does not lie in the realm accessible to the eye or ear. Active thought springs from the "I"'s will to think and it breaks through to the beholding of ideas in outer reality. The power of judgment at work in it appears to be individualized in a twofold way: on the one hand, from the side of the outer reality in question; on the other, by the "I" who is thinking. The specific stamp in the intellectual sphere, which results in this way, may be called style of thinking, which is not linguistic style, but which precedes the

latter when it expresses itself in language. The stimulation and formation of individualized power of judgment in the twelfth and thirteenth grades demands many sided practice through the acquaintance with various subject-oriented and individual styles of thinking.

The subjects basically deal with various areas of reality, each of which requires its own corresponding style of thinking. This already becomes apparent in the "overviews" which Rudolf Steiner recommends for German (English) history through art and history. They are not meant to be outer or systematically complete overviews; the concentration is on the field as a whole, on that which makes it a spiritual realm of its own which can be understood through a corresponding matrix of ideas. Thus we read in the curriculum for twelfth grade history: "In the twelfth grade our goal must be to lead the students below the surface, to bring to light inner qualities in history." Then he shows how through the concepts of antiquity, middle age and modern age, cultural cycles can be understood as whole, broken or incomplete. In history through art, Rudolf Steiner mentions key ideas both for the history of art and for the character of the arts: "Of greatest importance here is Hegel's aesthetic buildup: symbolic art, classic art, romantic art." In twelfth grade physics the opportunity presents itself to contrast the interplay of light and matter according to Goethe and according to Newton and to characterize these two fundamentally different styles of thinking. The various chapters of Goethe's Color Theory can reveal that there is not only a physical, an historical or an art historical style of thinking, but that various styles of thought can appear in one science in its various fields. This culminates in Goethe's statement: "Each object, rightly seen, calls forth a new organ within us." The counter tendency to this is found in the striving to apply one style of thought only, the "scientific" one, to all realms.

The organ referred to by Goethe is that part of our capacity for ideas which is called upon in a specific way by the perceived part of outer reality. This determination by the world is the one side; the other is the formation of the thinking process by the I, which, when true thinking occurs, becomes an individual, unmistakable style of thought. A student of the twelfth or thirteenth grade is particularly open to this; he takes up various styles of thinking, tries them out, sometimes identifies himself intensively with one and thus schools his sense of individuality, develops individual power of judgment. The study of literature and philosophy, which will be touched on later, presents a good opportunity to train this faculty as they deal with concepts and

pictures which are the foremost elements in a style of thinking.

"I will tell you of three transformations of the spirit: how the spirit becomes a camel, the camel a lion, and finally the lion a child.

There are many difficult tasks for the spirit, the strong, carrying spirit with its indwelling reverence: its strength demands greater and ever greater difficulties. . . . But in the loneliest of deserts the second transformation takes place: here the spirit becomes a lion, he wishes to win his freedom and to be the master of his own desert. Here he searches out his last master; he wishes to become the enemy of his last god . . . to rob freedom from his love . . . But tell me, my brother, what can the child achieve which even the lion could not?

The child is innocence and forgetting, a new beginning, a game, a wheel that rolls out of itself, a first movement, a holy "yes." . . . now the spirit wants his will, the lost one wins a world."

In Nietzsche's beautiful Zarathustra speech "Of the Three Transformations," the concepts have almost completely become pictures. Bearing, robbing, creating slowly come forth from: camel, lion, child. The path of thought is replaced by a proclamation filled with pictures. The thoughts are hardly built up by reasoning; they are simply posited and therefore usually appear in main clauses. The thoughts are not reduced to pictures, they spring into pictures which bring forth new pictures out of themselves. Rudolf Steiner proceeds differently. In his book *Goethe's World View* he carefully investigates the relationship between percept and concept in the creation of a judgment throughout two pages in the eleventh section. Then he writes: "When we apply our thinking, only then does outer reality become truly determined. Silent beforehand, it now speaks a clear language. Our thinking is the interpreter who reads the gesture of experience."

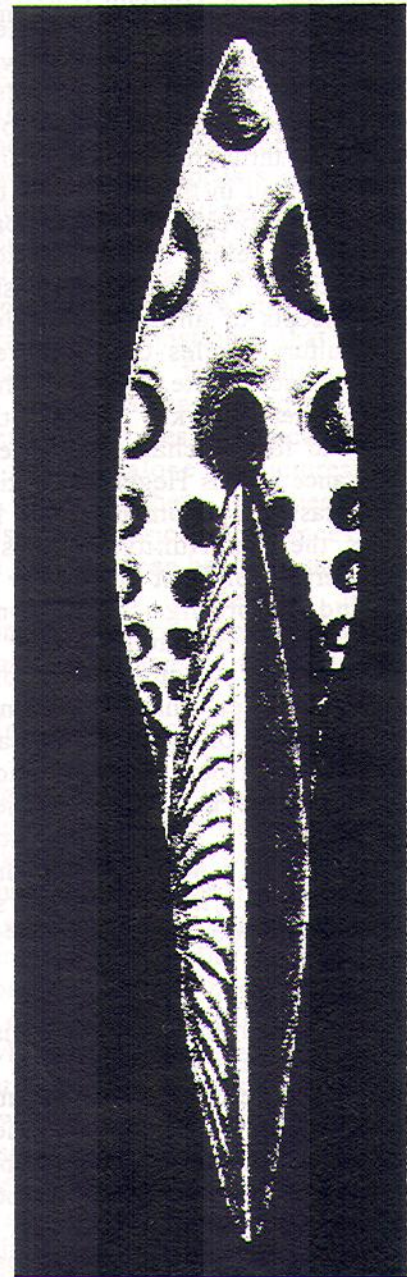
The first sentence summarizes a carefully guided cognitive process. It is the result of the preceding train of thought. Then the last half of the sentence is concentrated into a picture and its intensity is thereby enhanced. Then the image of the interpreter is added which concentrates the first half of the sentence. The picture of the gesture is then brought in, which is later conceptualized as "empty form." Such images are one with the thoughts. They give the thoughts spiritual visibility. One can dwell upon them with one's consciousness, and one does not forget them.

Here is an example of Goethe's thought style (*The Metamorphosis of Plants*, Section 113): "When we observe a plant in as far as it expresses its life force, we see it occurring in two ways, first through *growth*, as it brings forth stem and leaves, and then through *reproduction* which is completed in the structure of blossom and fruit." The formation of concept occurs here in the observation and remains one with the observational process throughout the paragraph. The two concepts of growth and reproduction grasp two expressions of life, but are essentially different concepts. "When we observe growth more closely, we see that, as the plant unfolds from node to node, from leaf to leaf, in its sprouting, a kind of reproduction taking place which distinguishes itself from the reproduction through blossom and fruit, which occurs *all at once*, in that it takes place in *successive* stages, in that it shows itself in a sequence of individual developments." The concept of growth takes on a more definite shape and transforms itself into successive reproduction. This thinking is alive, metamorphosing. The thoughts follow the processes. The sentence structure unfolds and pulls itself together organically. Goethe's individual power of judgment is a visual one.

Besides scientific and literary texts one also deals with sociological ones which also reveal individual styles of thinking, for example, that of Karl Marx. "...within the capitalist system all methods of enhancing society's productive capacity of work occur at the expense of the individual worker all methods of developing production turn into methods by which the producer can manipulate and exploit, which maim the worker and make him a partial human being, degrade him to an appendage of a machine, destroy the content of his work through its pain, alienate him from the spiritual potential of the working process to the degree that scientific potential has been incorporated into it; they destroy the conditions under which he works, subject him to the most narrow-minded, viscous despotism while he works, transform his lifetime into working time, cast his wife and child before the judgment wheel of capital. . . The accumulation of wealth at one pole is therefore at the same time an accumulation of misery, tortuous work, slavery, ignorance, brutalization and moral degradation at the opposite pole, i.e. for the class which produces capital as its own product." (*Das Kapital*) One notices numerous concepts derived from Latin which indicate scientific explicitness.

The numerous relationships, expressed as laws, give the impression of scientific objectivity. All of it, however, is imbued with a deeply rooted

inner engagement, with subjective feelings which are expressed in frequent one-sided, strong concepts.



Computer Science and Computers in the Waldorf School

Suggestions for the Technology Curriculum

by

Thomas Schmidt

translated by Mel Belenson

The critical importance attached by Rudolf Steiner to lessons in life studies, especially in the upper grades, is stated with particular clarity in the first of his "Lectures on Popular Education" (GA 192) given on May 11, 1919. These lectures were given in those months in which he was engaged in negotiations with Emil Molt in regard to the founding of the first Waldorf School, a time when he was not yet constrained by the necessary compromises of a real, functioning school.

"... From the fourteenth year on, those things must be dealt with in the lessons that appeal to judgment. Therefore, all those things can arise which, for example, relate to the logical understanding of reality ... All lessons must offer life studies. Everything that is related to the study of farming, industry, trade will have to be taught at the age of 15 to 20 years, but in a reasonable, economic way. No person will be allowed to go through this age without having received an idea of what happens in farming, trade, industry, business...."

In the fifth lecture of the so-called "Supplementary Course" (GA 302) given on June 16, 1921, the pedagogical reason for lessons in technology is explained with particular intensity:

"Generally speaking, it is the characteristic, the infamous characteristic of our time that the human being lives in an environment that is completely unknown to him. Go down to the street where the streetcar turns in, look at the people who are standing there waiting for the streetcar, and consider how few people know the way that this streetcar is set in motion, how natural forces are at work to enable the streetcar to be set in motion. You can well

believe that this has an inner effect on the constitution of the human being, the spiritual, soul and bodily aspects! There is a great difference if we go through life knowing or not knowing at least the basic elements of that within which we live. Making use of means of transportation or other devices without knowing the basic elements means for the soul-spiritual being blind. Just as a blind person goes through the world without knowing the effects of light, in the same way people go through the civilized world today because they do not see, have not had the possibility of understanding things. That is a soul-spiritual defect. And that is the damage that occurs in civilized humanity, that people are blind in relation to what exists around them."

UNRECOGNIZED TECHNOLOGY - THE "INFAMOUS CHARACTERISTIC OF OUR TIME"

Especially if we take Steiner's concern seriously, it is absolutely necessary to adapt the content of his curriculum suggestions to modern development, particularly in the subject of life studies and technology. The "completely unknown environment" of the present-day is no longer the same as seventy years ago! Steiner, forced into compromises by anti-pedagogical demands for a final high-school examination (Abitur), states in the Teachers' Conference of April 25, 1923, in a way that almost shows resignation, "...We can introduce a lesson in chemical technology only as a new subject..." On the one hand, there is the question of whether the conditions for graduating from the state schools, which are adhered to in most Waldorf schools (at least those in Germany), are not actually more advantageous since this "offer of one lesson" would be expanded; and on the other hand, "chemical technology" of seventy years ago was undoubtedly the equivalent of "the most modern technology of the present-day."

But how is it today? Along with the actual chemical technology of the present-day, we have environmental technology, atomic technology, genetic technology and – not least of all – computer technology and computer science which permeates practically every social action of people today and – remaining unknown in accordance with its intrinsic nature – brings to most dangerous expression the "infamous characteristic of our time." It is very evident that the basis of atomic technology – atomic and quantum physics-- is not understood by most of our contemporaries; this lack of understanding is not harmless for all that, but it is at least overt, except for people who are totally ignorant about it or who are specialists. In computer science, however, the "infamous characteristic" is present to an extreme degree. Every user of a computer who has been even superficially introduced to a so-called high-level programming language (starting with BASIC or something similar) is misled into believing he understands, although it is only the ability to set unrecognized technical processes in motion that has been given to him; they correspond to mathematical and other logical processes only in a technical way and as an end-product, but not in accordance with reality.

THE THREE DANGERS OF "ARTIFICIAL INTELLIGENCE"

Several fundamental dangers for the activity of human civilization come together here: *On the one hand*, through computer elements or computer-like control mechanisms, assembled on user-friendly handy devices, an intoxication of total power without any need for work (whether spiritual or physical) is produced; *on the other hand*, however, through the cold logic of systematically functioning mechanisms, control is taken out of the hands of human beings, imperceptibly and behind the polished control panels at the "causal thread" of electrical processes.

But with the "artificial intelligence" of the computer a *third*, even more deeply penetrating danger has come into the world in recent decades. This was described in a particularly pithy way by the American computer expert Joseph Weizenbaum in an article in the newspaper "Die Zeit" of December 5, 1980, especially in regard to the nature of human language.

"Human language is an extremely fine and powerful instrument. It is, of course, also limited, even handicapped. Its handicap is precisely this critical dependency of its function on the biography of its speaker and listener. Just this is also the strength of language. How I understand a really

important message is essentially determined by my life experiences, it is unique to me. From this fact there arises the uniqueness of the human being and the natural identity of every individual person. The central dogma of artificial intelligence, however, maintains that intelligence itself, and therefore also the manifestation of intelligence we call language, has its origin in a physical system, mainly in the brain, and can be fully described with the laws of physics. For this reason, it must be able to be simulated in digital computers. What is pitiful about this extreme reductionism is that it denies to history the decisive role that it plays in the development of humanity and of the individual. This fundamentally unhistoric, or rather anti-historic, attitude leads of necessity to the doctrine according to which the meaning of the utterances of language is somehow to be found in the utterances themselves, thus independent of the author. Ergo, the meaning lets itself get caught permanently in complex computer data structures, like 'semantic networks'. Consequently, the human speaker is detached from the world in which he lives and is considered only as one of the species of the more abstract kind of 'information processing systems' in which the computer is naturally the main species." And: "The danger of artificial intelligence is not that machines think more and more like people, but rather that people think more and more like machines."

This third danger is that the human being receives the suggestion that the core of his individual personality is nothing other than a complicated computer. In fact, the computer, especially in the form of a processor for controlling robots in industry and elsewhere, possesses (almost) all the qualities that – seen from the outside – makes a human being human. "Sensors" correspond to the sense organs; their signals are processed in the central unit – the computer's "brain" – and produce "deeds" by controlling electrical power units of practically every machine and appliance. There are even robots that control their own "feeding" by themselves: if the built-in battery is just about used up, the apparatus localizes through special sensors the nearest power source to which the robot connects itself "by itself." "Learning processes" are also possible: a properly programmed chess computer becomes capable of turning into a chess master within a short period of time with only the help of the rules that have been programmed into it; it stores all the moves made (at first according to chance numbers) with the pertinent chess-board configurations and later uses only the successful ones.

But what is the human being? Why he should be more than a complex data processor is, in

fact, not easily understood, especially when in some no longer distant future computers will, in the event of damaged nerve paths, take over the transmission of sense stimulation in the brain or, the reverse, the transmission of signals from the brain for controlling artificial limbs! And even today, under civilization's increasingly difficult conditions, is it not often seen as the school's task to "program" children so that they may cope adequately with life?

The simultaneously infinitely small and immeasurably large difference between computer and human being can be experienced only in one's own consciousness through "results of soul observation in accordance with the methods of natural science" (sub-title of Rudolf Steiner's *Philosophy of Freedom*, GA 4) – and that, too, only in rare "stellar moments" of human existence. Just as the quality of the color red cannot be "proven" to someone born blind, it cannot be "proven" to someone that the human being possesses an autonomous and freely creative core of personality if he has not experienced it himself within himself, this inner space of the creative "nothingness" that must lie between experience coming out of the past and every free decision to act that points to the future. Of course, this cannot be classroom material, not even in twelfth grade, but it is necessary to remove the obstructions that result from the above mentioned threefold suggestion of the computer which continues to go unrecognized.

A contribution can be made toward this "demythologizing" of the computer in every grade of a four-year Waldorf high school. One of the possibilities for such a passage through the grades of the high school is presented here.

GRADE 9: LOCOMOTIVE, TELEPHONE, BINARY CALCULATOR

In the ninth grade, the physics block can be the occasion for approaching the problem historically for the first time. Along with taking up topics in astronomy, Steiner gives the suggestion to come to an "exact" understanding of the telephone and locomotive. It is quite characteristic that both technical achievements were, in their own way, pre-conditions for earthly humanity to perceive itself as a homogenous unit; we are able to participate in the destiny of other nations and races without regard to their distance from us. This purpose was served by the steam engine which, in the railway locomotive and in navigation, made possible the first communication in world wide transportation, independently of the adversities of nature. This purpose was also served by the telephone that is able to create practically "timeless" communication in

space between the various places of the earth. It is more than merely historical accident that the piston control of the steam engine constructed by James Watt in 1769 and the automatic telephone dial system invented by the American Strowger in 1892 are important early examples of "intelligent" controls and thus immediate precursors of modern computer technology. Even the two basic types of data processor programming have their prototype in the steam engine control in which the supply of steam through a lever mechanism is brought to where the power is needed; this is "hardware" control by means of a set of permanently installed technical instruments. The procedure for dialing the telephone with the aid of a selector dial brings about the desired connection through the "input" of numbers; this is nothing other than a "software" program, that is, the controlled generation through coded signs of various technical functions in equipment that is, itself, unaltered.

Of course, the goal for a ninth grader, immediately following the transition to an awakened capacity for judgment and the conscious discovery of the highs and lows of one's own personality, is to further deepen an understanding for modern technical achievements; if possible by natural scientific practical work in small groups. For 15 year olds it is not yet age appropriate to study the imperceptible functions of modern semiconductor electronics; for this the more discriminating capacities for judgment of the 17 year old eleventh grader are needed. But in ninth grade it is not only a possible, but even the optimal point to exhaust the possibilities of how far human intelligence can come with electro-mechanical means; electricity, itself invisible, appears each time as a mechanical process.

After studying the electro-magnetic control processes by means of relays in connection with the procedure for dialing the telephone, and after presenting in mathematics in addition to decimal numbers other number systems, like the twelve system and especially the binary and hexadecimal system (2 and 16 digits) used in computers, the rudiments of a binary calculator on a relay basis can be dealt with in the practical work. For example, first the logical conjunctions "AND" and "OR" as well as negation in grammar can be constructed as relay switches with the students. "AND" can be explained by an example of strict upbringing, "OR" as less strict. Thus, if David empties out the trash can (A) "AND" sweeps the hall (B), he gets an ice-cream (C); $A \text{ "AND" } B = C$. If David empties out the trash can (A) "OR" sweeps the hall (B), he gets an ice-cream (C); $A \text{ "OR" } B = C$. If "yes" equals 1 and "no" equals 0, we have two equivalents of so-called Boolean algebra. Transformed into electrical

circuits, "1" means electrical voltage or current flow and "0" means no voltage. Now if an electrical switch is so constructed that with "C" electrical voltage is present or not present according to what is logically the correct case, a light, for example, might come on or not come on, then this is called a "logical switch" or a "logical grid." From several such "AND" and "OR" grids an adding machine for binary numbers can be constructed. Apart from the storage of data, these "logical switches" are the most important basic elements of modern systems of electronic data processing. The binary hole-punch card (hole = 1; no hole = 0) on paper tapes or cards can be studied at this level of understanding as a functioning program and system of storing data.

This way of studying the rudiments of modern data processing – and, as far as possible, carrying out experiments – has the advantage of making it understandable to a ninth grader; and as an historically real "entry" into modern technology whereby data can be collected, it is appropriate to the threshold situation of the 15 year old: the passage from the age of personal authority working from "outside" to the unfolding of the capacity for independent judgment. In Waldorf education this age begins with the historical presentation of the era of "discoverers and inventors" as the corresponding threshold situation for humanity and continues to modern present-day civilization. Lesson blocks and practical work in ninth grade physics can continue these generally historical presentations of seventh grade in several important aspects: the mechanical storage of data in punch cards and a limited processing by electro-mechanical sorting machines began in Germany as early as 1910 through the "German Hollerith Machine Society" in one of the most modern industrial works of the time, the Bayer paint plant in Elberfeld. In 1941, the first fully functioning programmable relay calculator, built by Konrad Zuse, was introduced in Berlin. It had a storage capacity of 1488 binary digits, contained 2000 relays and required 3 seconds for the multiplication of two 22-place binary numbers. This suffices then for grade 9.

GRADE 10: FROM THE SPINNING WHEEL TO THE AUTOMATIC LOOM

In tenth grade, according to Steiner's suggestions, the technology lessons proper begin. They are separate from the main lesson blocks in natural science because, in accordance with the progressive internalization of the process of forming judgments on the part of the adolescent, the emphasis in the chemistry and physics lessons is shifted from the aspect of life studies and technology to a more cognitive-methodical side: the

themes are a cognitive-theoretical integral acquisition of mechanics in the physics lesson and the basic processes acid-salt-base in chemistry. For lessons in technology and life studies technical drawings, the screw, surveying and especially spinning and weaving are mentioned. The relevant passage in the Teachers' Conference of June 17, 1921, reads as follows:

"...The beginning has to be made by studying tools like the spinning wheel, loom and so on, starting with primitive spinning and weaving There must be a knowledge of the material. And secondly, the cultural-historical development in the form of stories. In this way it can be spiced up; the students must of course become familiar with the more complicated forms since the elementary ones are no longer used."

It is quite clear here that for the acquisition of abilities of the craftsperson Steiner put equal value on the historical development of spinning and weaving *technology*. This aspect of the first independent technology lessons is mentioned here in such detail because, as we know, in the industrialization of the 19th century the automation of the weaving mill contributed to a very great extent to the exploitation and pauperization of the workers. A decisive point of departure for the automation of the loom, in addition to the "hardware" aspect of putting machines in the place of human muscle power, was the historically first "software" programming of a technical apparatus; this was the automatic loom invented in 1805 by the Frenchman J. M. Jacquard which was operated by any number of variable code signs. The threads of the warp can be raised and lowered by lever and bar singly and independently of one another. The important thing, however, is that the intelligence of a human being is no longer needed; rather, this control of the warp threads occurs automatically by means of a punch-hole code in a paper tape that automatically advances one line of holes with each "woof" of the shuttle.

Unnoticed in the simultaneously occurring heydays of ideas and ideals in the middle European classical period was the fact that an important step of civilization was made, comparable to the invention around 1450 of letterpress printing with movable type by Gutenberg; but the alienation from reality went a distinct degree further because now the identity of form inherent in the type and found in the copy and in the finished product no longer existed.

GRADES 11 AND 12

While the content suggested by Steiner 70 years ago for the technology lesson in connection with the points of view described above is topical enough, it is still necessary for both the upper grades to reorganize it and bring in additional material especially if the requirement mentioned by Steiner is to be fulfilled, namely, to deal with "modern and recent achievements" in connection with the physics material suggested for grade 11. Of course, an expansion of the material cannot be matched by an equal expansion of the number of weekly lessons. The problem can be somewhat lessened by carrying through the technology lesson with one-third of the class in grades 11 and 12 parallel with practical biology, chemistry, physics or computer science; for two weekly lesson that the students have, six lessons are scheduled for the teacher so that the individual adolescent is better served. Computers and computer science can then take up one part of practical chemistry and physics of grade 11 and the entire practical physics course in grade 12. Not unimportant even today, naturally, are the topics of grade 11: "Paper manufacture" in practical chemistry and questions of the economics of energy and the technology of the turbine in practical physics, but they would have to be restricted to one part of the course, and perhaps the relevant questions of national economy mentioned by Steiner (Conferences of June 21, 1922) can also be taken over in part by the lessons in politics or sociology that are usually given today.

GRADE 11: SEMICONDUCTOR DIODES AND TRANSISTORS

Electronics, which underlies modern computer technology, appears in eleventh grade as almost compellingly applicable to the chemistry and physics blocks of this school year since in chemistry the chemical elements are to be studied as "arrested" chemical processes and in physics, as already mentioned, the "recent achievements" of the science of electricity are supposed to be taken up. In this connection, it is suggested in the practical chemistry course to deal with the manufacturing process of semiconductor materials, especially those having silicon as their basis, which are fundamental to modern electronics. By "semiconductors" is meant materials which permit only an electrical current of *one* polarity, but that work as an insulator for the *other* polarity. The anti-natural "technical abstraction process" should be made clear; it is with this process that practically completely pure silicon single crystals are chemically grown and then "endowed" with foreign material, that is, saturated in a dilution of approximately 1:1,000,000.

Important is, of course, that the silicon, keeping a balance between acid and base, play a main role in semiconductor technology, this metallic shining material that can be obtained from clear rock-crystal, or more cheaply from sand quartz.

In the appropriate part of the physics course experiments are done with the silicon semiconductor elements – as diode, transistor "endowed" as a rule with antimony and indium, or solar cell "endowed" with phosphorus and boron. After the rectifying functions of the diode and control or amplifying function of the transistor have been understood through experimentation, the next task should be to assemble logical switches (which under favorable conditions were already constructed with relays in ninth grade) out of transistors and also to produce the bi-stable multi-vibrator. This is an electronic switching element, called a "flip-flop," that changes with every "impulse" by a short-term electrical voltage coming from the outside into the other of two possible electrical states. An example of a *mechanical* "flip-flop" would be a vertically clamped and therefore bent flexible sawblade that is only able to equalize its tension either by bending to the right or to the left. Such "flip-flops" are fundamental and important short-term storage elements for binary numbers in every computer; it is only that one of the two possible states must be seen as "0" and the other as "1". "Flip-flops" are absolutely useless as long-term storage since they lose their information when the working voltage is turned off, just as the mechanically released sawblade no longer bends to the right or left. For the historically first computers, punched paper tapes were used as long-term storage. Today substances containing iron and magnetized by impulses of current are used, usually in the form of magnetic disks ("diskettes"), magnetic bands or single magnetic storage units.

The complete construction of a binary adding machine from logical switches can be discussed at this point (under optimal conditions in ninth grade, but it can be *repeated* here). Since we now have the potential core of the central calculator of a computer before us, this can be repeated as well at the beginning of the course in computer science in grade twelve.

GRADE 12: UNDERSTANDING THE PRINCIPLE OF COMPUTER FUNCTIONS!

In the Waldorf School, what must be the foundation of a grade 12 course in computer science? Learning high-level programming languages cannot be the immediate concern since it does not yield anything pedagogical. A completely untrained

sixth grader might be able to produce a "basic" program, as can easily be ascertained by a visit to computer sections of department stores. It is a question of understanding the principle of computer functions; how far "immersion" in technical details goes depends certainly on how much expertise and interest the teacher has. It is especially important, and for the 18 year old twelfth grader also possible, to convey an understanding for and insight into the subtle mixture in modern computers of similarity with and contrast to the human being, as already described at the beginning of this article. If time is short, then perhaps the following aspects will suffice:

1. Important for the "demythologizing" of the computer, so pedagogically necessary, is to convey an understanding of its most important inner functions, first of all especially the transfer of data between the central calculator and the data and program storage; secondly, the transfer of "addresses" through which certain locations for receiving or transmitting data are opened; and thirdly, the transfer of control data in a steady flow between calculator and storage through which correct coordination and execution of the programmed commands are achieved. The similarity to the activity of the human mind is hard to deny. Does not our brain-nerve-sense organization work in the same way?

An example: The program is the definition of the concept of the triangle; through my intellect the "files" for angle, straight line and points are opened in my brain and the content transferred to my central organ. In accordance with the planned "program" links are established there, results such as "A triangle is formed by three points in space and the three straight lines determined by them, and the sum of its interior angles is 180 degrees" are filed in the category "polygon."

The so very important and yet barely noticeable way in which this differs from the human being is that a process of this kind once started in the computer cannot stop by itself and make room for another, unless that too was programmed in ahead of time and a list of priorities were available telling under what conditions which program was to give precedence to another. And even the so-called "chance number generators," with which the computer's supposed freedom of choice is suggested, work systematically, albeit in a complicated way that is usually not understood. And that is just the point! Of course we must be clear that not only do most of our "mental acts" proceed according to set patterns that are "pre-programmed" in our organization, but this is also true of leaps from one

mental act to another. Only, what makes the human being human is the principle of *potential* for free mental (spiritual) presence. Every truly creative act occurs completely out of the situation of the present, without programmed stipulations, yet it flows out of the center of our personality, which indeed lives in history however is not a product of it, but rather has the possibility to bring into the world something that was not thought before and was, until that moment, unthinkable.

2. It is enough to write small programs with a very simple content; it is only important that the teacher write programs with the pupils in "machine code," that is, with the program code of the calculator itself. If the program is in "high-level" programming languages, for example FORTRAN, Basic, Logo, etc., the code signs of the input must first be changed into the machine language with a "translation program" that was permanently installed beforehand. The procedures which can make possible an understanding of the internal structure of the calculator are withheld from our consciousness. If such a "machine program" that contains no data input and output then runs, the first reaction in most cases is, "My calculator is broken!" From this can be seen that the calculation process is absolutely imperceptible and if something is displayed, then during the display no internal calculation is running (apart from modern large-scale units with several compound calculators). And again the similarity: It is also a part of being human to be able to keep one's feelings to oneself; on the other hand, it does not seem human if inner activity is not accompanied by *any* outer expression at all. In such a case, the core of the personality, the "I" or ego, does not do justice to the task of permeating and harmonizing our *entire* being, and such a person appears to be robot-like and impersonal!

3. These conclusive findings, that the internal, actual running of the program and the communication with the environment are mutually exclusive, should be examined more closely with the students. What a huge amount of programming is needed to transfer only a single digit in its correct mathematical meaning from outside into the calculator, or to bring a digit from the calculator to the display when only the internal machine code is available. This should be investigated by means of experiments with examples of programs, for here the contrast between the human being and computer is singularly expressed. If a healthy person needs to make a special effort not to have his inner soul processes accompanied by facial expressions, a computer has need of especially great expenditures to produce a communication between outer world and internal running procedures. It is an expression of this fact that all the machines used for the input

and output of data are so much more costly and expensive than the actual calculator itself.

APPROACHING THE DIFFERENCE BETWEEN HUMAN AND ARTIFICIAL INTELLIGENCE

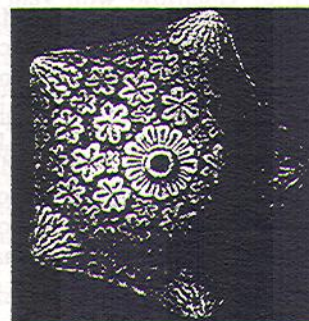
Given the discriminating capacity for making judgments now found in the twelfth grader – but certainly hardly any earlier – it should be possible to approach, in the way described above, the difference between human and artificial intelligence. Even a learning computer is subject to the prior input of a program with its pre-determined system, and even the forgetting of stored data requires programming! The human being, on the other hand, is in each creative moment in a "nothingness," left alone without being tied to any system, but permeated with an "I", or ego, out of which this "creative nothingness" is filled not with a pre-determined content, but with a meaningful content nonetheless; the "I" must also let go of the content by forgetting if it is to remain capable of existing as an autonomous individuality.

If the teacher does not take on the task described above, he or she immediately stands at another important juncture "with his or her back to the wall," and that is the troublesome usage of the pocket calculator! It is easy to see that this usage is worthless for gifted students and even harmful and obstructive for less gifted ones. For example, the feeling for numbers and size that says, even without calculating, that $0.43 - 0.57$ cannot possibly be 0.06 , this inner experience in which mathematics proper is grounded without the use of algebraic expressions, cannot be developed in students who have no particular relationship to mathematics when the basis for the relevance of such a feeling is denied them through the use of a pocket calculator. Since ninth and tenth graders demand from their teacher openness to the world without compromise, they accept much more willingly the argument against the use of pocket calculators at school, which after all creates inconvenience at first, if their justified interest in automatic calculating machines is not dismissed but rather if work is done in an age-appropriate way on their understanding, and especially if reference can be made to the course in computer science in twelfth grade.

Finally, something else should be mentioned. When it is said that the use of high-level programming languages is pedagogical worthless in the classroom, then an important qualification is needed. If there is the possibility of doing meaningful work in groups with the methods of modern data processing, for example in connection with school office assignments, that should be very

much welcomed for eleventh or twelfth graders and not bound by any kind of pedagogical restrictions in regard to the programming language and tools used. Of course, such projects have to be accompanied at all times by a positive and critical approach to the set of social and individual problems caused by the computerization of our world.

Important in the technology and life studies lessons of high school is first and foremost the struggle with the "mortal enemy" of every free initiative, that is, the resignation of knowledge, the idea that the world around us is not understandable – that has already been mentioned as the "infamous characteristic of our time," even much more so than in Steiner's time! Young people between 15 and 20 years of age must in no way be left in the illusion that the world in which we live is everywhere *good* or *beautiful* as is appropriate for the kindergarten or primary school years, but they must gain the conviction that the world is *true*, that is, knowable, if only they will make the effort!



Edward Miller is the editor of the Harvard Education Letter, published by the Harvard Graduate School of Education. His most recent book is Ready to Learn: How Schools Can Help Kids Be Healthier and Safer. The above essay was originally published, in slightly different form, in Newsday, Garden City, New York.

TECHNOLOGY IS NOT THE KEY TO BETTER SCHOOLS

by
Edward Miller

"Every classroom in America must be connected to the information superhighway," President Clinton told us in his *State of the Union* address.

My reaction was: Why?

The assumption underlying this and other simplistic prescriptions for remaking American schools with technology is that all you have to do is put kids in front of computers and they will be instantly turned on to learning.

If only it were that easy.

Computers, like blackboards, calculators, and televisions, are tools that teachers can use wisely or poorly.

In the hands of a teacher who knows her students well and can focus their efforts on the mental skills they most need to master, such tools can be powerful. Without the knowledge and guidance of a canny teacher, however, computers can be an enormous waste of time, effort, and money.

New technologies have always held out both promise and pitfalls for education. When the television was first introduced, we were told that it would revolutionize schools. It would bring a whole world of knowledge, culture, and art into the classroom. Researchers conducted studies supposedly proving that televised instruction was more effective than a live teacher's.

No one makes such claims for television now, even though we know there are some excellent educational programs and some perfectly appropriate uses for television in school. We're also aware, though, of the harm that television has done to children.

The computer also holds great promise. It has enabled children with certain disabilities to be integrated in regular classes. It can connect teachers via the Internet in virtual communities of practice, to share problems and solutions with colleagues across the country. It is an astonishingly powerful tool for scholars engaged in serious research.

None of this means that every classroom or even every school must have computers. Many thoughtful educators, such as those in the notably successful Waldorf School network, argue that younger children especially most need concrete, physical, and artistic learning experiences. Every Waldorf student must learn to play a musical instrument, not operate a computer. Most technology experts agree that the goals of schooling should be that children learn to use their minds well, to ask good questions, to write and speak cogently, to grow as human beings – and that using computers doesn't guarantee any of these things.

Don't kids need computers in school so they can get jobs later? No. The hardware and software of those future workplaces don't yet exist. The students best prepared for them will be those who have learned to use their brains – not Windows 95.

In far too many schools teachers and students work under conditions so discouraging that the phrase "information superhighway" sounds like a joke. They would rather have heard President Clinton say, "Every classroom in America must have adequate heat, unbroken glass in the windows, and a roof that doesn't leak, and be connected to a decent bathroom with toilet paper in it."

Even teachers with well-equipped classrooms almost universally lack adequate opportunities to learn--about new technologies, about the latest developments in their special fields, about strategies for helping kids who present an unprecedented array of behavioral and learning problems. Most of all, they need time to get to know each student and his unique talents and needs. It is short-sighted to spend scarce education dollars indiscriminately on more hardware and software when we could invest in something that will never be obsolete – the strength and capacity of our teachers.

Technology is important, and the President is right to focus attention on the need for equal access to its benefits. But technology will not solve most of the problems of schools.

If we know one truth about education, it is this: learning takes place in the context of human relationship – especially in that rare and tenuous web of connection between a knowing, caring adult and a student whose mind and heart that teacher or coach has touched. Such teachers use many different tools: poems, geometric proofs, lathes, saxophones, the stories of their own lives. Some even use computers.



COMPUTERS IN EDUCATION

[A section of the article by Arthur Zajonc, Physics Department, Amherst College, "Computer Pedagogy? Questions Concerning the New Educational Technology, from "The Computer in Education – A Critical Perspective", edited by Douglas Sloan (Teachers' College Press, New York, 1985).]

In my work as a physicist and teacher I use computers, large and small, constantly—whether to interactively run complex experiments in laser spectroscopy, to perform calculations, or to write this article. Perhaps because of this, the "mystiques" of the computer has faded the more I have grown to respect its usefulness. The idiocy of those who maintain that one must start young to master the machine can be explained only by their complete unfamiliarity with computers. It is not a piano, which demands years of training and practice to operate. Especially as more and more effort goes into making programs or canned packages "user friendly," the computer becomes increasingly easy to use. This is not to imply that no intellectually exciting horizons exist in computer science, but that is an entirely different question.

Let me also say that I see little harm in encouraging adolescents (older than about twelve years) to use the computer. I would hasten to add that any curriculum should be balanced with vigorous programs in more traditional subjects including the arts, but this is obvious. My questions primarily concern the child at those stages of development before the "abstract" or formal operation period, that is, before the age of twelve.

We are used to hearing complaints about computers replacing the teacher. As serious as this is, my primary concern is that the computer may replace the growing child. Consider the various components of any computer system: the central processing unit (CPU), the memory, and an input-output (I-O) device. Imagine the most powerful computer you care to: The CPU runs at blazing speed, the memory is practically infinite, and the I-O device is the most sophisticated touch-screen, color-graphics unit conceivable. Now add to this impressive hardware the software that certainly will one day be possible. It is a completely conversational and interactive language cueing not only on keystrokes, but perhaps on verbal or gestured commands. In one scenario this might be utopia for a computer-based pedagogy. To me it presents the problems in their most intense form.

The computer is like a fragmented projection of the human psyche. Each of its functions replaces one of our own. Just as we have replaced the child's active imagination (that is, the exercise of assimilation) through television imagery and certain toys, so the computer has the potential to replace nearly all the mental functions of the child. For example, memory has been found to be an essential factor in the successful operation of transitivity ($A = B, B = C$, so $A = C$).¹⁵ We may possess the ability to perform this operation, but be prevented from doing so by an inability to retain all the elements in memory. The development of this operational ability depends, therefore, indirectly on the strengthening of memory. Reliance on an external device

"the computer" can easily weaken that faculty. I would maintain that entirely similar arguments can be made with regard to the computational and logical functions of the CPU and program elements. These can replace and thereby undermine the development of corresponding faculties in the child. If the capacity to imagine has been undercut by television, interactive computer graphics threatens to complete the assault. Simply by pressing a button the child can transform his visual field at will. The use of language is here intentional, for there is clearly no will involved. The child is a passive doodler in such a situation, captivated by the images it can apparently create. But there is no creation here either. All these activities have been usurped by the machine. No one would contend that physical therapy is obsolete because the wheelchair has been invented. Neither should the computer be allowed to assume those functions that act as the foci for child development just because it can do so.

We may now profitably turn to another of the points discussed earlier in action. Piaget and others constantly stress that later mental operations are interiorizations of earlier sensorimotor activity. This has been a basic tenet of Waldorf pedagogy for over sixty years. Waldorf teachers, following Steiner's suggestions, — suggestions, commonly have their students run a triangle before proving that the sum of its interior angles is 180 degrees. Seymour Papert in his book *Mindstorms* recognizes this element fully. In order to do "turtle geometry," one should walk the pattern. By observing what the body does we have the basis for both a concrete representation and later the formal or abstract description of that operation. The learning of represented and abstract operations must be based in action. But the computer distances us from action. It may assist in the development of formal operative functions, but it fundamentally interferes with learning at previous levels. We first execute geometry and mathematics through the coordinated activity of the body. The natural transition to the concrete or representational stage can be provided simply by pencil, paper, compass, and straight-edge. The equipment should be kept minimal, never intruding or exercising its own volition. The straight line should be drawn by the child, not the computer. Once again turtle geometry ultimately usurps important activities essential for the child's cognitive development. The turtle moves, not the child.

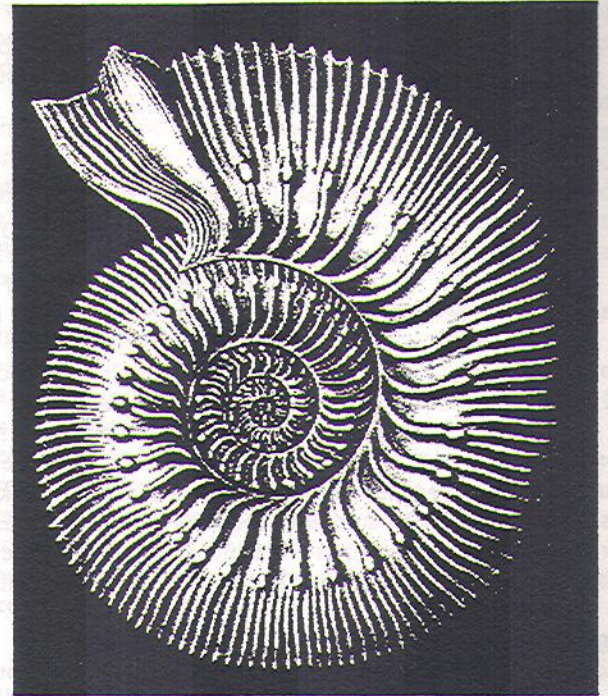
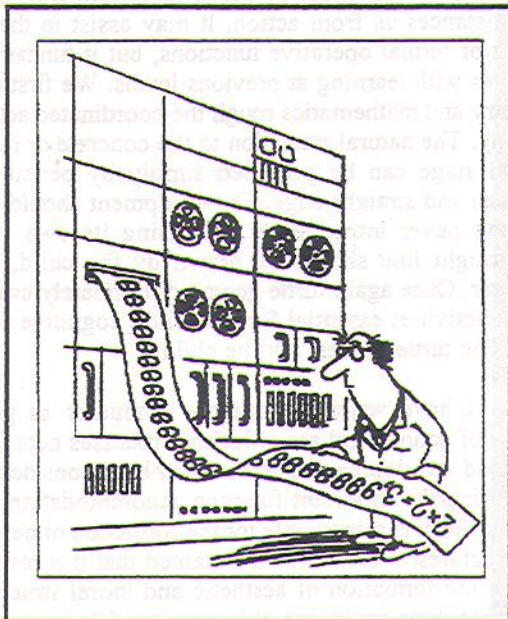
I have written about the computer as potential usurper of actions and assimilation, processes necessary for childhood development. I shall finish by reconsidering that extraordinarily important function accommodation, which, as I described, is responsible for the formation of new cognitive structures. Moreover, I maintained that it is responsible also for the formation of aesthetic and moral structures. In truth these three are inseparable aspects of the process of accommodation. When the child imitates it cannot filter out the cognitive component of the lesson from its aesthetic and moral aspects. It imitates the whole, and the whole should be worthy of imitation. Yet the use of the computer is predi-

cated on the assumption that cognitive structures can be cultivated in an aesthetically and ethically neutral environment. This is pure illusion. "No values" is just as much an ethical system as one that gives full conscious attention to them.

We must ask, in what sense can the child imitate a computer or its display? A pictorial answer is perhaps provided by the video-game imitations that fill current childhood behavior. The sounds and movements of Pac-Man become the movements of play. As much as I love technology, this image fills me with revulsion. On a less visceral level we may query after the cognitive structures we hope to induce via computer. If we learn, as Piaget maintains, through interaction of subject and object, indeed through actions in which "subject and objects are fused," so if new structures depend on the profound imitative capacity of childhood, in what sense can computers teach? Shall small children mimic CRT displays? Are the structures thereby induced the ones we wish to fill our society?

Put simply, the world of childhood, environment and teacher, should be filled with the movements, patterns, emotions, images, and actions that, when transformed, should underlie adult intellectual, emotional, and moral life. By attempting to neglect the inevitable presence of the latter two, and by inserting what is properly a device involving formal operations into earlier periods of child development, we risk doing violence to the orderly and natural course of child development. Time and again, we have attempted to outdo, speed up, or improve on nature. Technological advance is predicated on our ability to do so. Yet we must ask what should be done, what in the light of our best understanding of child development is an appropriate use of a powerful technology, and what is inappropriate.

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From Goethe on TV and Computers

Dummes Zeug kann man viel reden,
kann es auch schreiben,
wird weder Leib noch Seele rten,
s' wird alles beim alten bleiben

Dummes aber, vors Auge gestellt,
hat ein magisches Recht,
weil es die Sinne gefesselt hält
bleibt der Geist ein Knecht

One can say lots of foolish things
And write them down what's more;
This will slay neither body nor soul,
Everything remains as before,

But a foolish thing put in front of the eyes
A certain magic it will have,
Because it captivates the senses
And holds the spirit a slave.

* * * * *

Some Characteristics of the Computer

Introductory Remarks

by G. Kniebe

It may be considered an indisputable fact today that every pupil in school should have some experience with computers. Of course, there are differing points of view on what this experience should be. The curricula in public schools show the tendency to give the pupils lots of practice on the computer. As a result, things are often handled in an over-hasty manner as the following press report indicates:

"Computers are being acquired in numerous schools though there is a frequent lack of both proper programs for applying the computer and well thought-out concepts for the best way to combine use in the classroom and the school offices." (*Society for Mathematics and Data Processing*, quoted by the German Press Agency).

Waldorf teachers with related experience approach this issue differently. They have carefully

developed a program that aims less for the use and mastery of the computer but rather the understanding and construction of it out of its elements. Taking what they have tried out in their classes, they compared their experiences in colloquia, reconsidered them and finally put everything together in a working paper for their colleagues. This manuscript is now available in its second edition. The collection of suggestions and examples from the classroom is constantly being enlarged and corrected. After all, this is pedagogical virgin territory.

Only the entire booklet, "Sources, Characteristics and Dangers of Computer Technology" published by the Pedagogical Research Center in Kassel, Germany can give the willing specialist teacher the new impulses that he or she needs. However, the thoughts developed by Dr. von Mackensen in his remarks at the end of the booklet might be of general interest and are re-printed here.

Computers and Consciousness

by

Manfred von Mackensen

Translated

by Mel Belenson

I. WHAT DOES A COMPUTER DO AND WHAT DOES IT KNOW?

What a computer actually does is re-arrange electrical states. These states form patterns and structures that are arranged in various ways. The rules for this re-arranging are all pre-planned (the program), but the electrical end-states are *not* planned. They are governed by the beginning states (the data) that have been set up.

WHAT WE PUT IN

Along with the program it is necessary to *determine the meaning that must be put into the*

electrical 'end-states' or interpreting the "computer's output." For example, if the computer prints, "It is anticipated with 60% probability that this person will die a year from now," the computer of course "knows" nothing about dying. It does not "know" anything about the human being because it never knows anything at all. There is nothing within the computer of course that could have even the slightest relationship to the content of the statement that someone dies.

Any content – for example regarding the human being and dying – that connects the programmer with us in the space outside the computer still haunts our feeling in some way or

other through the computer and seems somehow to be managed within it. But that is not how it is. We only have the content available by request (requested by the programmer, not by the computer) in order to attach it to the signals that come flashing up. The meaning 'flits by' as it were, only along the exterior of the computer; it is 'passed along' as though by a note handed to us. This note is 'handed to us' by the programmer, usually via the screen. This leads easily to misunderstandings. On the screen, the following elements are mingled together:

a) The display of electrical end-states; these are the results of computing or processing, numerals, letters, text, primarily empty forms, that obey only themselves.

b) Impulses for interpretation in colloquial and technical language which, however, are not recognized for content within the computer, nor processed on that basis; rather they were written-in by the programmer or the user into these empty forms (which obey themselves), and which come streaming out again unchanged, but are then connected (in meaning) with the display of those electrical end-states by our observation.

THERE IS NOTHING AS DUMB AS A COMPUTER

Let us illustrate the situation again. Even if someone says a text is now to be "found in" the computer, this is not actually so. There is only an electrical voltage at certain points on a silicon wafer, in the RAM circuits, or in magnetic domains on a ferric-oxide diskette. The information has supposedly been "processed." We speak of processing signals, but that seems to require that the signals are also understood at the place where they are being processed (in the computer) – otherwise, how could they be processed? Here again we are easily misled. We have clarified already that all understanding circulates only along the outside: via the description of the program, the manual that accompanies the software and in the broad range of relevant technical and scientific communications available even without the computer. We considered that all the explanatory messages on the screen *bypass* the processing of electrical states, as far as their *comprehensible* content is concerned – the content that can be experienced and that affects the user in some way (in other words, their aspect of meaning which relates to the world). It is true that on-screen messages pass through the computer, but they also bypass its electrical activity. It is not the content of the meaning that enters into the electrical states but rather the formal structure.

This is a critical point in the whole evaluation of the highly acclaimed artificial intelligence, often praised in a way that is illusionary, idolizing technology, or highly over-

rating it. *There is nothing dumber than a computer.* It has only whatever mental flexibility that could be put into it in a rigid form – an unavoidable self-contradiction. It usually takes very little – a single deviation, a single faulty circuit, to lead to a 'crash.'

First, the problem or task must already be entirely understood. The computer cannot add anything to it; it only alters the formal structures inasmuch as the programmer thought something up *before* hand. It is like the shell around a hollow space which later sucks something from us and renders it again in chiseled forms. What has been sucked in, is forced into deadened thought forms of the past, forced into that which had been thought up by the programmer. What did he know of me and my life today? In a recent interview Joseph Weizenbaum stated simply, "A machine can *produce information* just as little as an electrical power plant can *create energy*."¹

By being available through the memory of such a huge system, the previously prepared thought forms, whose formal structures are imaged and restructured inside the computer, actually are always experienced by the user as so overpowering that he calls the computer his partner. "It didn't understand me," is what the user often says after an unsuccessful request has been made. Actually, a biographical-characterological portrait of the creator should be attached to every operating system and program, since it is that character which the soul of the user is constantly meeting. For example, there is Tim Paterson of Microsoft Corporation, the author of MS-DOS (Microsoft Corporation Disk Operating System) in Seattle in 1980. Since the computer understood nothing, one must actually say: "You didn't understand that, Tim." And then you might hear the faint answer: "That was dammed unintelligent what you requested." "OK, Tim, I'll try something else." The computer is often experienced as the rational person to whom one is relating. This weakening of the user's will is connected with something else again.

II COMPUTER COUNTING AND THE HUMAN EXPERIENCE OF NUMBER

The interesting thing about the single states in computer hardware – whether electrical (current, voltage) or magnetic (residual magnetism) – is that the user actually wants nothing to do with them. He cannot bear to be involved with them! If a computer had to be operated by directly engaging the single binary states without the built-in routines of the interface and the ROM (support circuitry), it would not be manageable. It would be necessary to

¹ Weizenbaum, J. "Computer Power and Human Reason" MIT Press, 1979, p274.

make millions of individual applications of 0 or 1 for an effective program. Such an effort gradually leads to agony, perhaps to a kind of hallucinative mental condition. Such formal soul-activity separates the nerve-sense system from the emotional and motivational aspects. Intermediary visions occur. Once the first error creeps in, *everything* becomes unusable. Then comes the search for 'the bug...' It would be easier to sort out grains of sand in the desert, which would actually provide a greater richness of perceptions and be more stimulating.

Basically, there is no counting and no numbers in the computer's binary system. After all, counting means referring to something with a repeated mental or physical movement. Because it is movement of the body, this is originally an act of deliberately connecting with the world. But here there is only "is" and "not" and then various place values, which are part of a [binary] numerical sequence, that is abstract and is merely agreed upon convention. A system of counted numbers can thus be projected onto it. This impulse is raised into thinking and the counting is done inwardly. If someone cannot sleep and therefore counts and controls the will in thinking, this person's subjectivity stops its fidgeting and the individual falls asleep. In the binary system, the will part is immediately discontinued, the rational operation of place value begins, and there is no way to ascend.

IIB. COMPUTER "LANGUAGE"

Since it is not possible to use the computer for very long in such a monotonous binary system (input and output in the binary system is called "machine language"), meta-expressions soon have to be defined. The first step is the hexadecimal system, a striking contrast to the binary system since it uses 16 digits, six *more* than the decimal system. But that too is unwieldy. The hex commands are designated by small acronyms in "assembler language." But even this is too difficult, so many assembler commands are collected into one Macro command, or into one 'high level' command in Pascal language, for example. All this is not 'language' but rather empty forms in which formal meaning, as understood by the program (that is, by the programmer and the user), can be put into them as definitions.

In 1950, the English mathematician Alan Turing, one of the early fathers of the computer, coined the term "computing" for machine calculation, which actually means mental arithmetic. This derives from *computare* - to calculate. We have seen that there can be no question of there existing in the computer even the remotest inner processes relating to consciousness that could lead to an experience of counting, to a judgment or to a

link with regard to its content. In this sense it can neither calculate nor count; as we have seen, it even robs the user of the possibility of real counting, unless they set up the machine in another way, through hex, assembler mnemonics, Pascal instructions, etc.

Thus it is also plain to see that there can *never occur any kind of language* in the inner processes of the computer. If we speak of programming language, we mean the psychic and organizational help for the user as described above.

Even if the computer cannot have an experience of it, does not the user at least enjoy the supposed "languages" of the computer? This is a good question, since language connects programmer and user. There we are misled. The following applies to every human language: What a single, isolated word means cannot be said in an all-inclusive, complete and absolute way with other words, since the same applies to the other words just as to the first word. A word forms its meaning only *by usage in connection with other words*. This connection is also somewhat dependent on the people who form the word or receive it. It becomes clear that the word cannot be defined satirically.

Language is also always a little bit art, context and personality. Otherwise it would never be able to bring us the mysteries of life. The "words" of computer language lack this character. The connections they call forth are fixed. That the colloquial interpretation of the command or its results can be a basis for discussion does not change anything of the rigid definition of the command in its interaction with others in the machine. The words of a programming language are not free working and interweaving impulses but rather bearers of closed definitions, similar to military regulations. It can be easily observed how, in the case of words deadened by definition, language is reduced to a barking such as can be heard on a drill-field. After all, computer language consists only of commands!

Suggestions, distractions, mood influences or images find no place in computer dialogue. Since all the 'words' are coded numerically for the machine, transformed by the compiler, and then interpreted by the operating system in "machine language," as a binary number code, they are limited and inflexible for the user. The programming language is only a system of grouping definitions, not a language. Words of a programming language differ from words of a real cultural language as a skeleton differs from living animals.

After having been led to a certain disillusionment by the fundamental contrast between the change of electrical states and what the user puts into them, we will, however, always be brought to a condition of admiration by the way architecture, operating systems and programs organize this

relationship. (see "Computer Technology" Chapter IV: 'MS-DOS for 12th Graders').

III. PSYCHOLOGICAL EFFECTS – WEAKENING THE WILL THROUGH THE COMPUTER?

The history of the computer begins, in the narrower sense, with Schickard (mathematics professor in 18th-century Tübingen). The task was undertaken to replace externally the forms of the results of the activity of human consciousness by technology, and only that! It is not the will in the muscles (machines) and in organs of perception (control instruments, automatic machines) that is replaced, but only in the nervous system, in this case thinking with the Intellectual Soul. Something technical and external replaces the forms that are otherwise produced internally, not the content.

If we are suddenly told "seven," a hard, thin something appears in our consciousness. If we also hear "seven days," or "seven Marks," or "seven in relation to six," then the irresolute search that was begun when seven was first called out receives a direction and thus a question can be formed. A movement in thinking begins, shadowy mental pictures flit by and are perhaps stopped somewhere. Now we can conjure up something in regard to this. We produce mental images; perhaps we ask questions and make guesses. Only when the seven *appears in some context* or other, or is arbitrarily referred by me to something else, does the rigid, dead identity "seven" receive any content. Along with the content it also receives at once a movement, it flows into something else. This is inherent in the ordinary fluctuating way of the human soul. Everything flows on. If we stay in the purely mathematical, the "seven" fills itself with arithmetic: seven in relation to six

Let us trace our way back. Out of a lively content we come again to the hard, thin something: the unrelated seven that was called out. In our thoughts we make this seven even emptier of content, poorer and more rigid. The caller must disappear, the situation, the time of day, my mood, when I heard the call, my associations: my life. Now the seven could be on a slip of paper, removed from any present time. But we do think of it as still present, in movement and in discussion, in changing combinations, in its effect on something else that is just as empty: then, inasmuch as we are making an approach with our consciousness, we have the process of the computer. Or more precisely: we experience, rather subjectively at first, what is the basis of the much more subjective and even naive experience we have when we enjoy the computer's performance – in contrast to the present direction of our striving, namely observing the "mode of thought" in ourselves.

In reviewing these concentration exercises, we can approach the following: there are somewhat logical forms, but without any experiential content. Such forms are passive and rigid in us. If, nevertheless, we bring them to movement, for example in doing a calculation, we exert ourselves, we are active out of a certain striving – we want to do the calculation. This striving arises in us only through experiences. A wish, a situation, a purpose or such-like *can* be experienced. Something or other leads or induces me. To that extent, these pictures and feelings beset the will in the thinking. The will as a soul-force in our reason, remains invisible; the calculation remains invisible for us and for others since I'm "looking" at the numbers. This will is replaced by the computer; or more precisely, by the residual will-forms from the programmers and system designers; they created them and left them behind to form a shadowy life in the machine.

So a definite form of human will, that is, a definite form of taking hold of the physical body – in this case, the brain – is not needed in the machine. This diminishes the will-nature and thus the earthly (physical) emergence of the human being. He becomes weaker at this point. The pocket calculator already causes limpness. Whoever "hangs" on the computer becomes "slouchy" in his sitting posture, as we often see.

There are certainly instances when it is right to replace one's own efforts and in so doing create free space for oneself, at the same time creating new human problems and even causing damage. Creating something new in this way and balancing things out would be a centrally human act if only it happened.

If the computer only replaces the will in thinking in an archetypal way, then the typical application of the computer would be to calculate, and the most untypical and dangerous would be to use it as a control device. For even in device control, calculations occurring within a chip are not communicating with the calculation in our consciousness, but rather, by means of servomotors, linking with the space of our limbs e.g., opening or closing of ventilation baffle, or switching on an oil-bath heater. Only calculation replaces mere will in rational thought; the other uses of the computer already replace something further, namely world-relatedness of a human being with an individual and moral nature, which is foreign to the computer. Already in using it for decision-making, elements of profit, print-out, and decision-making power now are included. Thus, we have the following increasingly problematic sequence:

Calculation

< Device control

< Text Processing

< Managerial Decision-making

In summary: as viewed from fundamentals, i.e., the sources and essential functions, the computer replaces will in thinking. Then it takes hold further of outer actions, which all kinds of machines do for us (automation).

STUDENT'S REACTIONS TO COMPUTER CLASSES

Initially, in working with keyboard and screen, interest arises. Then the students gradually divide into two camps. For the one group, it is too much: they do not understand the formal structures that seem alien to them, to their perceptions and to their life. Since for them there is too little of interest outside of manipulating the structures and formalities, it becomes hopeless for them. They feel that computer technology is of no educational value.

The other group grasps quickly: the students make it their own and, to the relief of their teacher, finally become involved in a subject and develop persistence. Such students, against all odds, completely open up, they are easy to lead and extremely eager to learn – they are often unrecognizable.

If the lesson is allowed to continue on in a steady way for too long without anything new and without practical work in which everyone has the same lack of previous experience, the computer freaks raise the level and tempo to such a degree that the group is polarized and actually dissolves; it goes as far as having feelings of condescension or hostility. The aim of every lesson in the Waldorf school, namely to bring the students together in their learning and experiencing, is missed because many students no longer know what the others are talking about. Obviously there is something here of the power of self-amplification both upwards and downwards; that is, it either presses outward or sucks in. And soon, a second phenomena is seen: no satisfaction is gained, even the "computer freak" is not satiated. Where does this come from?

The merely formal and defining character of the class content described above, in the last analysis leaves the user empty. We can read in Hartmut von Hentig: "In reality the computer is a closed, unsocial, unphilosophical and almost exclusively 'head' object for instruction; it not only obeys a system of coercion (economic-technological development), it is one itself. The computer is an ingenious abstraction of a certain human capacity and through this – through the isolated, undisturbed use of this capacity – it is enormously capable of performance and, simultaneously, enormously

'dumb'; we can recognize in it what we do not wish to be: a machine, not even just in thinking."²

What the computer accomplishes, also with us, is soulless. And yet, powerful will is required to wrestle the machine to the ground, to make it do what I intend it to do. But this will does *not* arrive at any soul-satisfaction, since it does not flow into any sort of real world. The person doesn't reach any peak of *harmonious* embodiment in the surroundings. The soul hardens in the thin, dry brightness of formal decisions; pounding the keyboard follows. It doesn't achieve a rhythmic weaving back and forth of *warmth and interest*, as is otherwise found in life. There is no completion in a sense of community. And, the subconscious feeling of emptiness in spite of mastery, goads one on again and again, to seek an unattainable satisfaction. Thus, someone who is involved in this way is driven forward as if by a craving. Joseph Weizenbaum, a master computer scientist, describes just such cases in young programmers in college.

In contrast, someone who is not so involved soon notices how he continually forgets what he tried so hard to learn. Because the concepts are formal, particularly one-sided in the way described – somehow without soul – they do not connect with a whole striving nor with feeling. They do not make any lasting impression on the normal human being who is developing by means of active life. This forgetting is actually a sign of soul-health. Soon, a further phenomenon appears.

IMPRINTING EVERYDAY THINKING - EVERYTHING CAN BE ACHIEVED IN RATIONALITY

We have seen that the computer relieves us of rational routines and data collection. But, this service requires innumerable pieces of information, and retaining them becomes a new burden. These data build a conceptual-analytic system, which is foreign not only to our experiential soul life within, but to our whole outer life. Whoever is totally immersed in such formal conceptualizations, will in proportion to the experience, slowly imprint the rest of their understanding of the world and their everyday thinking. How does this occur?

Every person carries within themselves, on the one hand, closed concepts such as numbers, mass, planning of periods, travel costs, traffic regulations, income tax, etc. In addition to these, are open concepts, existing as something entirely different, perceptually-saturated or more ideal concepts like color-qualities such as blue, beauty, excitement, grandeur, life, freedom, effort, conscience, etc.

² H. v. Hentz, "The Gradual Disappearance of Reality" Hanser Publ. Munich, 1985

Working with the former is necessary for daily life; to work with the latter, we have to be prepared to create them for ourselves. The conceptual system and commands of computer operation go even further beyond the former, in a more splintered direction, foreign to a synthesis. Industrious work on the computer displaces spiritual forces and capacities, because no counterweight exists in its formal orientation; qualitative, richly-experiential open-ended views disappear in its energetic goal-oriented grasp. Mono-causal, analytic thinking dominates. Things are reduced to a mere skeleton of themselves, that which can be logically and formally defined – leaving very little. But people forget this. Naturally, there arises a kind of quickness, clarity and overview in its outer aspects – thereby even a certain kind of heightened intellectual level, which then illuminates a materialistic outlook, that the human is like a machine.

Young people, many of whom dive into computer work, in wishing to clearly see the fullness of life-problems, are inclined to categorize and limit them; they presume without saying it, that everything can be gotten rationally in concepts. Something domineering comes to the fore in such people.

MASTERING LIFE - OR, THE SEARCH FOR THE RIGHT FEELING

Behind such activities, stands yet a further characteristic which the computer forces upon the people who work with it. Such people experience again and again: the implementation doesn't work, and the effects of an intellectual mistake lead to a 'hung' computer. Quickly their ingenuity flashes up, they understand the unforeseen error, its tiny but fatal inconsistency, and can quickly repair it. New programs must continually be scanned for errors, for unforeseen side-branches which occur under rare conditions; thus a slow process of 'debugging' follows every basic design stage. Slowly, the opinion takes root in the user that – even in the rest of life – every problem is quickly soluble if we can just locate the error, and that a dogged analytic understanding can instantly "switch off" the problem wherever it crops up. In fact, there is actually no real "problem," concern, or disaster. One only has to find the 'intelligent' place, a singularity which we just have to find.

With this, the human relationship to the world which comes through practice and self-development is gradually eliminated. By following many paths, and in wrestling to develop capacities, abilities, and solutions of life-problems, the weaknesses or inclinations which lie within us become unnecessary. Sometimes we have to turn ourselves inside out, take the issue entirely

differently, let go of established habits, begin anew. True, the computer inserts us into a complicated net, but one where all problems remain external. No deeper life capacities are exercised. The difficulties all cluster about a single point, for which we suddenly find the 'solution' or right formula, the right 'trick' and then we're finished. **This realm is dominated by a search for 'tricks' rather than effort and practice.** And, instead of being open and aware of the surroundings if something is to be achieved, the manner of working necessary for the computer more likely produces a habit of being closed off in a monotonous puzzle. Instead of working with the whole, the person make their way exercising great intellectual force around particulars. The user becomes a piece of the machine.

In the end, the person becomes estranged from riddles and problems that deal with human beings, the world or with life:

- They are deceived about the inward path; believe they can follow a linear causal chain through the myriad details; but less and less will they come to a real inner effort and self-transformation within the context of a larger whole.
- They are deceived about the solubility of world-problems; believe that it is only necessary to find the right "program" to apply, and then the power of technology will achieve everything.

WHAT SHOULD A SCHOOL DO?

Thus, we can formulate a basic rule: work with computers doesn't belong in the lower grades! The highest levels of the high school is the place to experience this one-sidedness, in order to become contemporary, and also to develop intellectual powers. In general, the students shouldn't be continually "crouching in front of the screen" nor prematurely prompted to equip their home as some sort of computer lab. The lessons in all the other subjects and the overall organization of the school are appeals leading their interest away from a fixation on the computer, out into all sorts of directions, opening up the world.

We have to ask: what can be a counterweight to computer-thinking? A school which teaches the fundamentals of computer technology in yearly increasing stages, should also cultivate the qualitative, phenomenological approach to natural science, in Goethe's sense. And, not just illuminate these aspects, but develop them in the students by doing (through the will). Even, in various places, slip in more will and more experiential work into thinking, in order to compensate for fewer computers.

EXPERIMENT

The following was downloaded from the National Science Teaching Association internet address, Scope, Sequence & Coordination project (SS&C) – Curriculum Micro Units” to provoke comments about significant mainstream curriculum work! J.P.

Weighing in Weightlessness!

How can we weigh something when we are weightless?

Overview:

When the space shuttle is in orbit, or while the Russian MIR space station is moving in its orbit about Earth, the astronauts aboard must frequently determine the mass of things. They determine the mass of food that they consume, waste products from their bodies, and may determine the mass of things in conjunction with the research that they are carrying out as part of their mission.

But how can an astronaut weigh something when he or she is in a weightless environment? A balance like you would use in a science class will not work. How then do they determine the mass of something?

In Activity 1 of this micro-unit you learned that gravitational and inertial mass are equivalent. If they are equivalent then we should be able to make something that will take advantage of inertial mass, measure mass with this device, and then recognize that our measurement is the same as we would get with a balance on Earth.

Your task is to invent and calibrate what the astronaut would call an inertial balance. Remember that inertial mass is a quantity that opposes changes in motion. Thus, any device you can think of that involves changes in motion should be able to measure inertial mass, and, therefore, gravitational mass.

Inertial mass opposes changes in motion. If the force is constant, acceleration is inversely proportional to inertial mass. Something that accelerates less than something else would, after the same time, move slower as well. Thus, we might measure inertial mass by how much it accelerates with a constant force. But when you accelerate something, it moves along a straight line by speeding up or slowing down. But it also could change its direction. That would also be a change in motion.

To make an inertial balance on Earth to use in space has an added problem. You have gravity to contend with here on Earth. So how can you make such a device?

Procedure:

The simple device uses a hacksaw blade that can vibrate back and forth. One end of the hacksaw blade is clamped to a table, and an unknown mass clamped to the other end. Then the end on which you have the unknown mass is set into vibration side-to-side, so that gravity is not involved. The rate at which the hacksaw blade can accelerate the mass back and forth depends upon the mass that has been attached. Now the problem is that the hacksaw blade and c-clamp themselves have mass, so part of the opposition to the change of motion is due to that mass. How can you separate out the unknown mass from that of the blade and c-clamp?

Clamp five known masses onto the end of the hacksaw blade, one at a time. Then for each of these masses, measure how long it takes for the blade to swing back and forth once. This is easily done by counting 10 or 20 complete swings over and back again to the same place and using a stopwatch to get the time for those 10 or 20 swings. When you divide that time measurement by the number of swings over and back, you get something called the period.

Graph the mass that you use on the vertical axis and the period for that mass on the horizontal axis.

You now have what we call a calibration curve for your inertial balance. You normally plot the dependent variable on the vertical axis, but this is different.

Once you have a calibration curve, then you can clamp an unknown mass onto the end of the hacksaw blade and measure its period of vibration. Then you read the graph of your calibration curve to see what mass corresponds to that period.

Another way to make an inertial balance is to use changes in motion, without change in speed. If you were in orbit on the space shuttle, where you experience weightlessness, swinging an object tied to a string around in a circular path creates sort of an artificial gravity for the thing being swung around. But to make this work as an inertial balance, you would have to swing it at exactly the same angular speed for all measurements, and that might be hard to do. Using circular motion might appear easy. You could tie a spring balance between your hand and the string going to the mass that is moving. It would give a certain reading, depending upon the mass being swung around and the frequency at which you are swinging it around. But to calibrate the spring balance you would have to keep the object moving at a constant frequency. The easiest way of doing this would be to tie the string to the center post of an old $33\frac{1}{3}$ rpm record player, with the mass sitting out at the edge of the disk. Then you could rotate objects a fixed speed. If you could see the spring scale reading clearly enough, then you could use several different masses at the end of the string and calibrate your inertial balance.

The ideas described above will work, but you need to design your own balance. So create your own design of an inertial balance, make it, test it, and when it works, calibrate it. When you are finished, you will be asked to measure an unknown mass given to you by your teacher. You will also be asked to provide your calibration curve.

Questions:

1. If your inertial balance is some version of the hacksaw blade device or something else that oscillates back and forth, how can you determine the *effective mass* of the balance when it does not have a mass attached where masses are measured? Is there a way that this could be determined from your calibration curve?

2. A student creates an inertial balance that vibrates side-to-side. This student got the following results when she placed various size masses on her balance:

Period of Oscillation second	Masses used for Calibration kg
0.224	0.100
0.316	0.300
0.447	0.700
0.524	1.000
0.725	2.000
0.880	3.000
1.012	4.000

Make a calibration curve for this inertial balance. Suppose that an unknown mass is placed on the balance and has a period of 0.652 seconds. What is its mass?

Mysteries and Myths

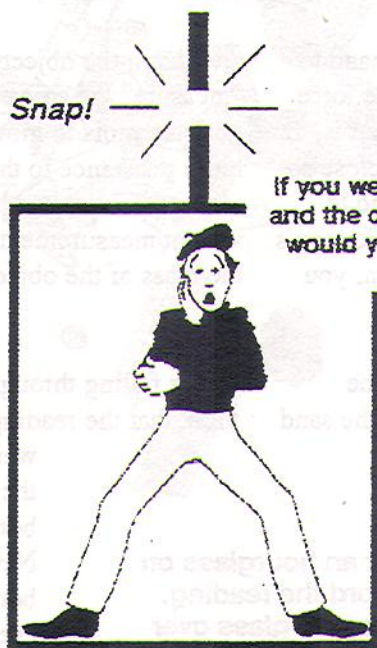
Let us assume that the elevator is not equipped with any sort of safety braking mechanism. If the cable were to break, then you would be in free fall. You and the elevator would be falling together. This is the same situation as that for the astronauts in the space shuttle in orbit around the Earth. You would be able to float freely in the elevator, pushing off the walls and drifting to the other side. Of course, your experience would be short-lived, as the elevator will eventually hit the ground! In reality, elevators are equipped with safety mechanisms that will not allow free fall in this situation.

Now, we can ask, why do both you and the elevator, or, for that matter, any two objects, fall with

the same acceleration (ignoring air resistance)? This stems from the dual role that mass plays. If we consider the mathematical form of Newton's Second Law, $F = ma$,

we see that the mass of a falling object plays a distinct role in this equation as resistance to changes in motion. But the mass also determines the force on the left side of the equation, since it is the gravitational force between the Earth and the object, which is proportional to the mass of the object. Thus, more massive objects are pulled down to the Earth with more force, but they also exhibit a

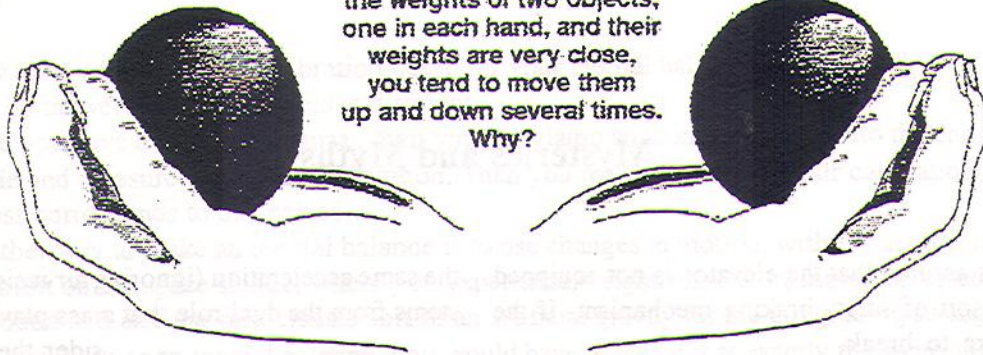
proportionally larger resistance to being accelerated. These effects cancel, so that all objects fall with the same acceleration.



If you were in an elevator and the cable broke, what would you experience?

(continued)

If you are comparing the weights of two objects, one in each hand, and their weights are very close, you tend to move them up and down several times. Why?



If you hold objects stationary in your hand to weigh them, you are actually measuring the force necessary for you to hold the objects up, that is, to cancel out their weight. If the weights are close so that you can't tell which is heavier, you tend to move them up and down. This is a use of Newton's Second Law. By moving them up and down, you

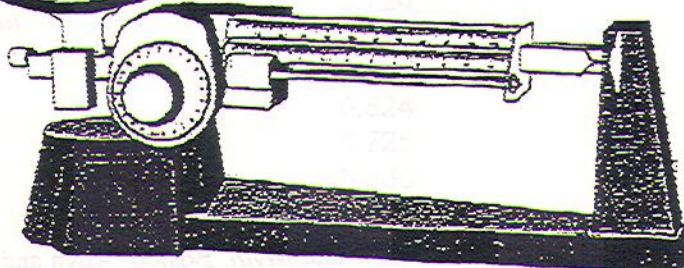
are giving the objects an acceleration. You then "measure" the force with which the objects resist your attempts to move them. The object that exerts more resistance to these attempts is the more massive. Thus, you have supplemented your weight measurement with a dynamic measure of the mass of the objects.

The scale will give the same reading. The hourglass does not exert a normal force on the sand

that is falling through the air, so you may tend to think that the reading will be less. This "loss of



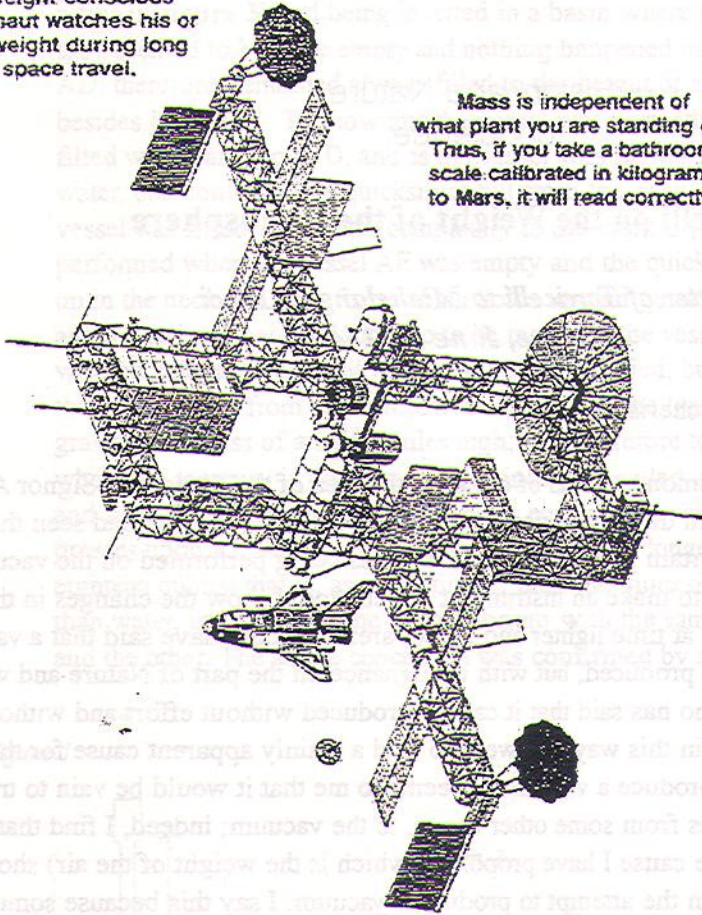
Suppose you set an hourglass on a scale and record the reading. You now turn the hourglass over so that the sand starts falling. Does the scale give the same reading while the sand is falling through the air in the hourglass?



weight" is balanced, however, by the force of the sand hitting the bottom of the hourglass. By Newton's Second Law, the bottom of the hourglass must exert an upward force, larger than the weight, to give this sand an upward acceleration, thereby stopping it from falling. This exactly balances the weight of the sand in the air, so that the reading is the same. There will be some fluctuations at the beginning and the end. For example, at the beginning, some sand is in the air, but none has hit the bottom yet. Thus, during this brief period, the reading will be lower.

A weight-conscious astronaut watches his or her weight during long space travel.

Mass is independent of what planet you are standing on. Thus, if you take a bathroom scale calibrated in kilograms to Mars, it will read correctly.



If you are on a rocket traveling in empty space, then you have no weight, since the gravitational field in your vicinity is essentially zero. Thus, you don't want to watch your weight, you want to watch your mass!

Even if a bathroom scale is calibrated in kilograms, it is still a spring scale. Spring scales depend on the gravitational attraction of the Earth to provide a reading, by stretching or compressing a spring. As a result, scales measure a force related to the weight, they do not measure mass. Thus, the bathroom scale calibrated in kilograms will give an incorrect reading on Mars. Mass is measured by a balance, in which gravitational forces on objects located on either side of a pivot are in equilibrium. Thus, a balance taken to Mars will still provide correct readings of mass.

History and Nature
of Science

Torricelli on the Weight of the Atmosphere

Letter of Torricelli to Michelangelo Ricci
Florence, June 11, 1644

My most illustrious Sir and most cherished Master:

Several weeks ago I sent some demonstrations of mine on the area of the cycloid to Signor Antonion Nardi, entreating him to send them directly to you or to Signor Magiotti after he had seen them. I have already intimated to you that a certain physical experiment was being performed on the vacuum; not simply to produce a vacuum, but to make an instrument which would show the changes in the air, which is at time heavier and thicker and at time lighter and more rarefied. Many have said that a vacuum cannot be produced, others that it can be produced, but with repugnance on the part of Nature and with difficulty; so far, I know of no one who has said that it can be produced without effort and without resistance on the part of Nature. I reasoned in this way: if I were to find a plainly apparent cause for the resistance which is felt when one needs to produce a vacuum, it seems to me that it would be vain to try to attribute that action, which patently derives from some other cause, to the vacuum; indeed, I find that by making certain very easy calculations, the cause I have proposed (which is the weight of the air) should in itself have a greater effect than it does in the attempt to produce a vacuum. I say this because some Philosopher, seeing that he could not avoid the admission that the weight of the air causes the resistance which is felt in producing a vacuum, did not say that he admitted the effect of the weight of the air, but persisted in asserting that Nature also contributes at least to the abhorrence of a vacuum. We live submerged at the bottom of an ocean of the element air, which by unquestioned experiments is known to have weight, and so much, indeed, that near the surface of the earth where it is more dense, it weights [volume for volume] about the four-hundredth part of the weight of water. Those who have written about twilight, moreover, have observed that the vaporous and visible air rises above us about fifty or fifty-four miles; I do not, however, believe its height is as great as this, since if it were, I could show that the vacuum would have to offer much greater resistance than it does—even though there is in their favor the argument that the weight referred to by Galileo applies to the air in very low places where men and animals live, whereas that on the tops of high mountains begins to be distinctly rare and of much less weight than the four-hundredth part of the weight of water.

We have made many glass vessels like the following marked A and B with necks two cubits [figure 1]. We filled these with quicksilver [figure 2], and the, the mouths being stopped with a finger [figure 3] and being inverted in a basin where there was quicksilver C [figure 4], they seemed to become empty and nothing happened in the vessel that was emptied: the neck AD, therefore, remained always filled to the height of a cubit and a quarter and an inch besides [figure 5]. To show that the vessel was perfectly empty, the underlying basin was filled with water up to D, and as the vessel was slowly raised, when its mouth reached the water, one could see the quicksilver fall from the neck, whereupon with a violent impetus the vessel was filled with water completely to the mark E [figure 6]. This experiment was performed when the vessel AE was empty and the quicksilver, although very heavy, was held up in the neck AD. The force which holds up that quicksilver against its nature to fall down again, has been believed hitherto to be inside of the vessel AE, and to be due either to vacuum or to that material [mercury] highly rarefied; but I maintain that it is external and that the force comes from without. On the surface of the liquid which is in the basin, there gravitates a mass of air fifty miles high; is it therefore to be wondered at if in the glass CE, where the mercury is not attracted nor indeed repelled, since there is nothing there, it enters and rises to such an extent as to come to equilibrium with the weight of this outside air which presses upon it? Water also, in a similar but much longer vessel, will rise up to almost eighteen cubits, that is, as much further than the quicksilver rises as quicksilver is heavier than water, in order to come to equilibrium with the same force, which presses alike the one and the other. The above conclusion was confirmed by an experiment made at the same time

Figure 1

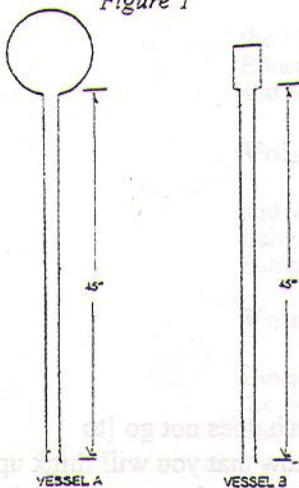


Figure 2

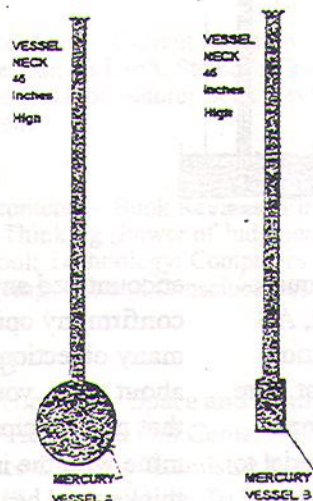


Figure 3

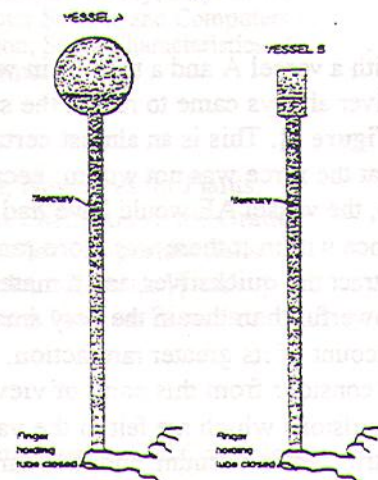


Figure 4

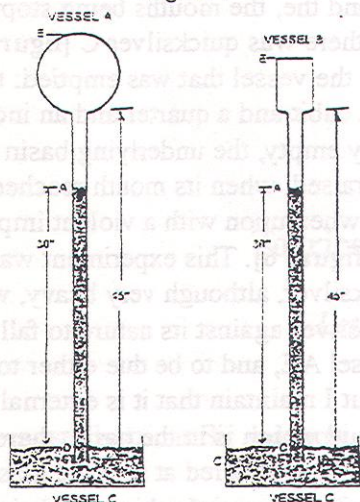


Figure 5

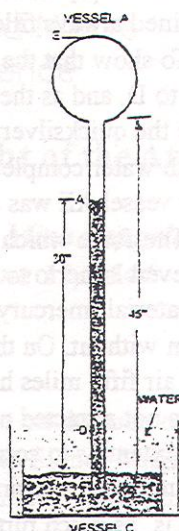


Figure 6

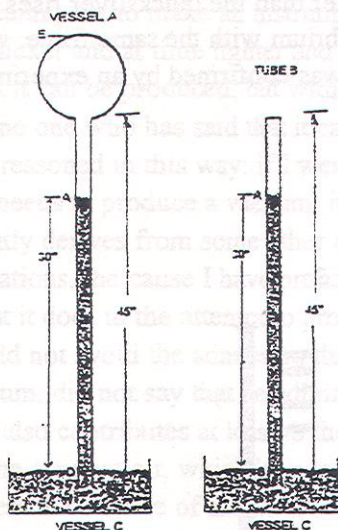
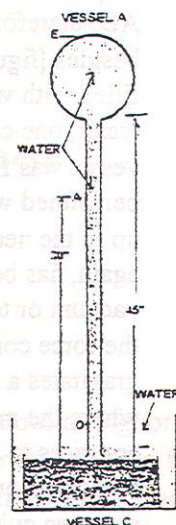


Figure 7

with a vessel A and a tube B, in which the quicksilver always came to rest at the same level, AB [Figure 7]. This is an almost certain indication that the force was not within; because if that were so, the vessel AE would have had greater force, since within it there was more rarefied material to attract the quicksilver, and a material much more powerful than that in the very small space B, on account of its greater rarefaction. I have since tried to consider from this point of view all the kinds of repulsions which are felt in the various effects attributed to vacuum, and thus far I have not

encountered anything which does not go [to confirm my opinion]. I know that you will think up many objections, but I also hope that, as you think about them, you will overcome them. I must add that my principal intention—which was to determine with the instrument EC when the air was thicker and heavier and when it was more rarefied and light—has not been fulfilled; for the level AB changes from another cause (which I never would have believed), namely, on account of heat and cold; and changes very appreciably, exactly as if the vase AE were full of air.