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WALDORF SCIENCE NEWSLETTER

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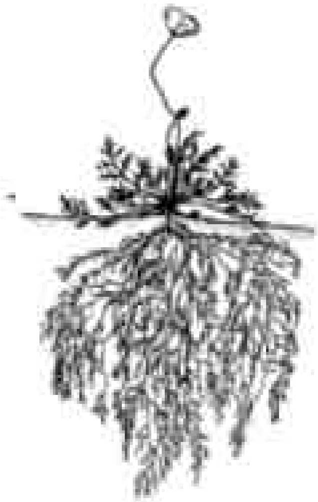

Waldorf Science

Explorations in Phenomenology as Practiced in Waldorf Schools

A Science News Roundletter

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NOTE FROM THE EDITORS

This is the first *Waldorf Science Newsletter* to be sent electronically to all schools. This form of distribution will save us considerable expense; we will continue to make paper copies available through AWSNA Publications at a nominal charge. The current *Waldorf Science Newsletter* and all past editions can be accessed On-line at >www.awsna.org<. Please continue to make copies for all the colleagues in your school who find this Newsletter valuable.

Currently there is a lot of independent research being undertaken (see next page for details). It has been a goal of the *Waldorf Science Newsletter* to promote this research and we are pleased with the quality of the work being produced and the fact that it is available from AWSNA Publications.

We are also pleased to announce that the On-line Waldorf Library (http://www.waldorflibrary.org) has made many articles readily available to all teachers. If you haven't visited this website we recommend that you do. There is a lot of material including a listing of all past editions of the *Waldorf Clearing House* containing many valuable tips for teachers. This can be a valuable resource for a teacher's preparation.

SPECIAL NOTICE

This June's annual AWSNA Conference to be held at the Kimberton Waldorf School from June 22-26, 2002, will be unique. The title of the conference is "Ascending the Developmental Staircase" and is inclusive for all teachers from preschool/ kindergarten and elementary grades through high school. There will be displays of the work of the AWSNA Waldorf High School Research Project including the *Proceedings* from the Research Conference held last October in Andover, Massachusetts. These Proceedings contain four important lectures by Dr. Michaela Glöckler. Dr. Glöckler will be speaking at the June Conference on the birth of the etheric heart as related to puberty and the children of the middle school. She will also lead sessions on the pre-school child and child development in the elementary grades. This, of course, is just one of six special presentations on child development. The editors hope that many of you will take advantage of attending this special conference.

The following research material is available from AWSNA Publications:

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Waldorf High School Research Conference, October 2001

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Sand flea (Orchestia agilis), amphipod (Crustacean)

Inside the Gulf of Maine

by

Sue Hubell

I live on a rocky hillside overlooking the Gulf of Maine, a shallow sea within a sea. Its entire shoreline, with all its irregularities, is said to be 7,500 miles extending from Cape Cod to Cape Sable, Nova Scotia, and contains within those encircling promontories 36,000 square miles of water.

I have my morning coffee looking out over my bit of the Gulf. From my windows the view is bounded by protective islands that tame the full force of waves and weather. But a short hike down the road takes me to pink granite cliffs from which I can see out to the horizon. The waves break directly there and send spumes of salt water high into the air. It is one of my favorite places. I like to sit there and think about all the lives being lived out down under the surface, lives we don't see much unless we see photographs like these in the article that Brian Skerry has shot in the Gulf of Maine. We know surprisingly little about those animals; we haven't even identitified all the ones that live here, and much is unknown about those we have labeled with a name even those of some economic importance to us.

Salt water copepod (crustacean) (Pleuromamma spp.)

But we do know a few things. We know, for instance, that the geological history of the Gulf has helped shape everything that exists in it. Sitting on that raw rock, one can easily understand that the Gulf of Maine, geologically speaking, is a young place. Estimates are that it was formed about 16,000 years ago. We wouldn't have recognized it then, for it was configured differently, but the glaciers that had locked up so much of the ocean water and weighed heavily on the land were in retreat by then and had sculpted the place. It was different even 10,000 years ago when, archeology proves, people were living along the coast. Warmer waters flowed here then; swordfish swam in them. Carbon dating of their bones shows that they were here as recently as 4,000 years ago, a time so near ours that it is hard to measure on a geological scale. But soon after that, the warm waters retreated and the swordfish followed them. By then shifting debris from the melted glaciers and rising waters formed a coastline very much like the one we see today.

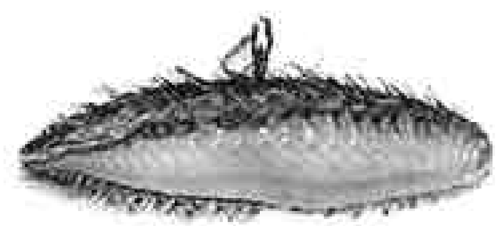
Just as significant to the present Gulf and the lives being lived out within it, however, are the things the glaciers left behind that we cannot see until we go underwater: the shoals called George's Bank (off Cape Cod) and Brown's Bank (off Cape Sable). They provide a barrier to the Gulf Stream's warm water, which meets cold Arctic currents in the open ocean beyond them. The shoals channel the arctic Scotian current around Brown's Bank and on up into the Bay of Fundy where it creates those famous tides.

A male lumpfish, having turned mating-season red, aerates and guards a female's eggs. Lumpfish eggs are harvested for caviar.

The cold current swirls along the coast of Maine, New Hampshire, and Massachusetts. But by the time it reaches Cape Cod, the Earth's rotation deflects it back to the north and east, forming a circling gyre which, modified by tides and seasonal temperature swings, creates a home place full of food and opportunity for a surprising array of plants and animals.

We tend to think of tropical places as lush centers of biodiversity, and, generally speaking, that is true on land. But in the sea the opposite is true. Cold waters hold more of the dissolved gases that plants and animals need and allow thick blooms of phytoplankton, the tiniest of marine plants. Mixed by big tides and upwellings (tropical waters lack both), the phytoplankton provide a feast for zooplankton—the smallest of animals, often the larval forms of bigger ones—and bigger animals prey upon both. In addition. the algaes we call seaweeds—long-fingered bladder wrack and sinuous kelp, for instance—provide more nutritional fodder in the Gulf of Maine than in any other similar place on earth. Invertebrate animals such as sea urchins graze directly on them, but as they decompose, their fragments form a rain of food debris for smaller animals.

A person walking the Gulf's shores cannot help but notice an amazing number of seabirds feeding alongside. That person will also see at least some of the 26 species of mammals, whales, seals, and porpoises that make the Gulf their home for at least part of the year. Big fish, clams, mussels, scallops, shrimp, crabs, and starfish are all also familiar residents. But in addition to these animals, there are a great many seen only by scientists and divers. So far, 1,600 species of bottom-dwelling organisms have been identified living in deeper waters. We are largely ignorant of their lives and the relationships within that underwater community, and yet zoologists suspect they are vital to the entire ecosystem.



A Sea Mouse (Aphrodite aculeata)

My own favorite is a beautiful, big, furry worm with a golden pelt that turns to shimmering iridescence—blue, green, purple, magenta—when brought to the surface where it catches the light. That seldom happens, for it has no commercial value, and it's at home only in the mud of sea bottoms. It dies quickly at reduced surface pressure. Other than having given the worm a name—Sea Mouse (Aphrodite aculeata)—we know virtually nothing of its life or how it relates to other animals.

The top predator in the Gulf, at least for the past 200 years, has been us. Once, great auks, the Arctic's answer to the penguin, migrated in uncountable numbers through the Gulf and even nested on its islands, but they were hunted to extinction by the middle of the 19th century. The great auk is thought to be the first animal we extinguished in the New World. The last sea mink, a larger animal than its woodland cousins, indigenous only to these waters, was trapped in the 1860s. The only remaining hunter-gatherer agriculture—fishing—has nearly eliminated the big finny fish from the Gulf, although they still swim farther out to sea, where trawlers net them in floating freezer plants. With care they might make a comeback. They preyed on smaller animals, and so their disappeance in the Gulf affects the numbers of many of those, green sea urchins to name just one. In the decade past, urchins were raked up by divers for the lucrative Japanese market but were taken such large quantities that they, too, are now dwindling. Zoologists do not

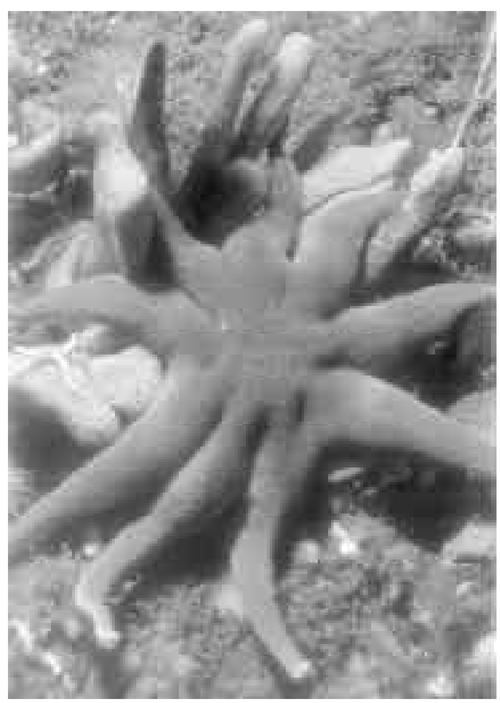
A northern red anemone has a mouth that accepts small fish and other food from more than 100 thick tentacles.

have enough data to understand population cycles in underwater communities, but they theorize that the reduction of sea urchins may have allowed the kelp upon which they feed to grow more extravagantly, giving better cover to lobsters that are now being fished out of the Gulf in greater numbers than at any time in the recent past. And what will the result of that be? There are strong opinions about the matter, but no one really knows because there is no data on what a "normal" baseline lobster population might be, or even if there is one in these everchanging waters.

Sometimes our predation and disruption are less direct. Space allows only a couple of examples:

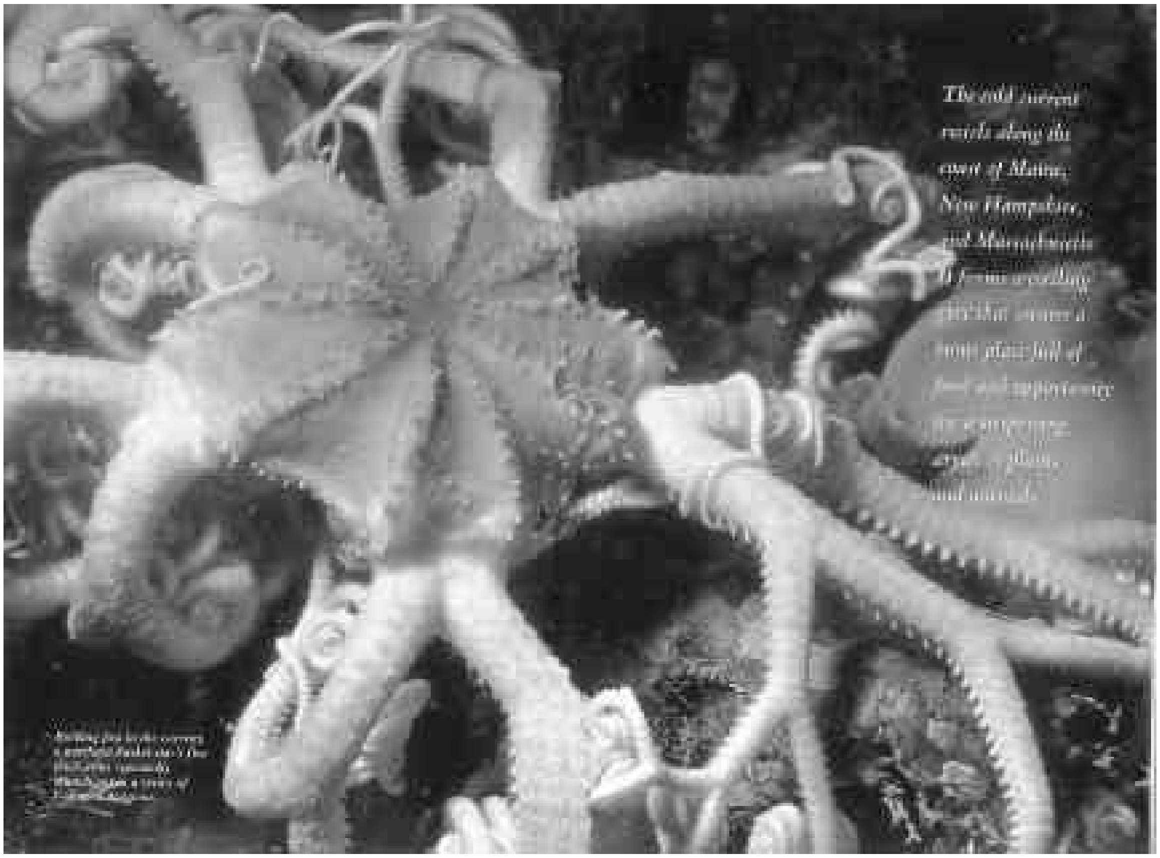
• Dragging weighted nets to capture sea cucumbers, scallops, and shrimp is a little like forest clear-cutting. It kills a lot besides the targeted species, and it messes up a big swath of territory.

• Just as the midwestern prairie was given over to grain and hogs, parts of the Gulf of Maine are being set aside for aquaculture. With fish or corn or hogs, farming changes things. There are genetic muddles, accumulation of animal wastes, addition of chemicals and antibiotics, which, in the case of the Gulf of Maine, spread and swirl through the gyre.



The spectacularly colored sea star can be found at depths of 900 feet.

• Satellite imagery shows large plumes of silty, often chemical-laden run-offs from cleared and farmed land emptying out of the many rivers that feed the Gulf, as well as plumes of sewage outfalls from the cities strung along the coast. The gyre takes those within its mix, too.



We are a species that fiddles with parts of its environment in order to make things nice for ourselves. It is a human trait; we will continue to fiddle with the Gulf of Maine as we do with other parts of the world. Unfortunately, we don't understand very well what our fiddling does. We need to know more and we need to know it soon. Now that there are more than six billion people in the world and we have tools more powerful than ever before to work with, the demands we put on the world for the comfort of our own kind increasingly affect lives that are not of our kind. There may be a good deal of arrogance in the clumsy way we stumble through the world, harming plants and animals that had staked out claims to the planet long before human beings existed. But even leaving that point of view aside, there is a selfish reason for us to consider and learn something about the lives of other species. Those species make up the world we live in and have contributed to the physical, even chemical, environment in which we evolved as humans. And perhaps we humans can be quite happy without the sea otter or great auk as part of our environment. Perhaps cod and green sea urchins are not very important to our own personal ecosystems. But eventually, as more and more plants and animals are harmed, our own linked and interdependent ecosystems will be altered in ways that are at best unpleasing and at worst could be cataclysmic. Sponges, which have been around

Mucus-coated arms deposit plankton into the mouth of a hungry sea cucumber.

for millennia (they are here in the Gulf of Maine) and have survived the catastrophe that extinguished the dinosaurs and other like events, would probably survive the breakup of our ecosystem, but we probably would not. The paleozoological record shows that species that survive catastrophic events are those species that have survived earlier ones. Sponges have been tested; we have not. We are just beginning to develop tools that can help us understand—satellite imagery and underwater photography of the kind seen here are but two examples.

But more important than all the tools in the world is the fact that in addition to being fiddling animals, human beings are also driven by the power of beauty and are full of curiosity.

Back in the days when green sea urchins were plentiful, I spent a day onboard a boat with a crew of urchin divers, just off those pink granite cliffs beyond my house. The cliffs continue their abrupt drop underwater, and the divers were working at a depth of 40 feet. When one of them came up for a break, he told me that a few years previously he had been hauled up unconscious and given up for drowned. But a persistent medic had brought him around. He had every reason to fear the sea, and here he was diving again. I asked him why. “You know, it’s not even the money, although that is pretty good now,” he said. “It may sound silly, but it is so beautiful down there. The colors are unbelievable. Some of the animals are luminous and they do the strangest stuff. I like to try to figure out about all of it."

Never underestimate the power of strangeness and beauty.

The curious gray seal, once hunted to near extinction in New England, has made a comeback.

Printed with permission of the editors of *Yankee* magazine. This article appeared in the November 2001 edition.

Sculpted by evolution, a blue shark glides through the Gulf. Attached to its dorsal fin is a parasitic copepod.

Large canine teeth distinguish the Atlantic wolffish.

How Do Atomistic Models Act on the Understanding of Nature in the Young Person?

From Chapter 12, *Fields, Rays, Atoms,* a book on 11th grade Physics

By

Manfred Von Mackensen

After his introduction about the issues surrounding bringing science in a way that depends heavily on the model-based approach common in many physics books, Dr. Mackensen explores how we might do it another way and why. We invite comments on how you have tried to address these issues and hope to stimulate dialogue on this complex but crucial issue. — J. Petering.

Pro and con models in teaching

The abyss between naive experience and quantum theory (i.e. what scientists may think) is of course bridged in teaching—as is well known—with so called models; i.e. with visual, easy to follow simplifications. For the time being we are going to lay aside the epistemological and culturally critical doubts outlined so far, in order to consider the models—this central conceptual form of contemporary education—once more from a different side—in the context of teaching.

Educational consequences of model-thinking

The main question in regard to thinking in visual models surely is this: To which spiritual forces are they giving rise in the student as they strive to understand the world as it manifests itself to the senses?

The purpose of a model is always—as with any kind of explanation—to trace back the unknown to what is already known. In model-thinking however, those things known are chosen very one-sidedly. For in the beginning it is mostly concerned with the idea of primitive things (particles) which interact mechanically or maybe electrostatically. The real macroscopic fields of phenomena included in these ideas (e.g. mechanics) are far removed from the individual phenomena which they purport to explain. Thus with the mechanics of rigid bodies, for instance, the original (phenomenological) impression is far removed from chemical reactions: here we have impenetrability in space and permanence—there we have inner penetration of substance, disappearance and new emergence. The causal connection between the two, e.g. through applying the laws of impact to the reaction of gaseous molecules, normally is in no way considered to be a problem, rather a triumph.

Another example: One imagines the circular path of the electron to be maintained through the equilibrium between electric attraction and centrifugal force. Such an equilibrium is known from the planetary movements. The path of the electron therefore is a model, a visual representation, that is according to the pattern of macroscopic conditions. Since the macroscopic ideas —in our example the equilibrium in the paths of planetary bodies (satellites)—are very widely independent from their absolute dimensions, they were thought fit to be projected into atomic dimensions. This projection however, when it is made more and more concrete, leads to contradictions as was described above. For this reason in school book-literature it is usually said: a model only has as much value as there is clear awareness of the limits of its application. This surely means nothing less than—through using the model—giving up to penetrate into the whole of reality and to form concepts that can be applied to the perceptible whole. Moreover, through the model one is trapped in the particular segment of reality selected for interpretation. This is why the model is formed: the thing as a whole, as it appears in its own sphere, is not mastered by one's thinking and is, therefore, transplanted into spheres where it appears more clearly, i.e. mechanistically. From the opposite point of view this would be the very argument for the models (for their economy). In my view it is a call for a different approach.

Thus model-based thinking does not strengthen those spiritual forces in the human being through which he actively wants to familiarize himself with the world as a whole as it appears to the senses, in order to fathom, and work it through towards individually formed concepts—that is all that which could later on give confidence in science to the lay man. Instead it increases the dependence on changing questions of a specialist, kind and it trains a formal faculty of imagination and the deductive observation of isolated phenomena. The reason which model-based thinking is so tempting for contemporary man is because it limits soul activity down to the cognitive (intellectual) aspect which leads to an outer command over nature and which does not press for a deeper qualitative penetration of sense-realities. It confronts the latter only through recording (perception as signal) and through hypothesizing (superimposing a model). This is in accordance with an already existing preference of modern man and it thereby gains in popularity. Somewhat pointedly: In school teaching, models mostly lead away from the original self-discovering activity of perception and of thinking, away from the individual laborious path to clear undimmed experience; they are escalators to the heights of incompletely understood abstraction.

A second question must be: With how much understanding for the true facts of atomic theory does model-based thinking leave us at the end of schooling? Models in the early syllabus often project categories borrowed from the world of senses, i.e. categories of classical physics, into atomic structures. This bypasses—as outlined above—the actual nature of quantum type of phenomena and therewith the nature of atomic theory altogether—and after some steps it always leads to contradictions. Models want to shortcut what on principle cannot be cut short without writing off the most important part. But the most important part of wave mechanics and of the theory of relativity after all is that they *invalidate* naive (ontological) materialism. The premature models on the other hand *validate* the latter.

If one follows the contemporary premature introduction of model-based ideas, the students will hugely retain the *ancient* concept of the atom! To them the modern discoveries appear only as complication instead of utter invalidation. This development of thinking stagnates at the level of Ancient Greece. In this way, then, a “scientific world conception” arises through model-based thinking, as we had to describe it in its whole wretchedness at the outset.

An optimal factual understanding of the true facts in the area of atomic theory is therefore not achieved for the present and mostly it is even thwarted. For any later understanding is shifted through thinking—habits and cognitive debris—that is all that remains; all this will have to be cleared out later on.

Can models be justified as efficiency-increasing teaching aids?

In spite of all these shortcomings, the models could, as far as economy of learning is concerned, be considered to be so advantageous that one would still want to use them in teaching. In that case the impact of the above objections is usually softened by emphasizing (like all “progressive” specialist teachers and textbooks) the limits to each model. To do more than that is not considered feasible.

Here in particular the observation of the development of thinking in the adolescent can prove something different. Even if the teacher considers himself to be a Nominalist in the sense of scholastic categories—he does not come across that way in this area, as outlined at the outset. At least the younger student remains realist. Explanations of real phenomena he takes to be real! He will not understand that “limit” here means something much more complicated, that is, something to do with epistemology. The “limit” of validity after all means (generally speaking) that somewhere there is factual validity. However, the scope of validity of visual models in a real sense is zero. The model is (as an element of Beingness) nothing more than the phenomena that give explanations are without the model. In suggested curricula for high schools it is stated that “a model can never be wrong or outdated” since it is only supposed to summarize a pre-arranged selection of empiric facts for the purpose of simple imaginability and can therefore only in some cases be unsuitably arranged. If now at the same time it is said that the model always contains only one part of the truth, then the previously rejected ontological substitute is unintentionally being admitted. Going beyond the mere impression of the senses, the model is supposed to produce explaining, substantiating truth—up to certain limits, it is true, and in piecemeal fashion, but truth nevertheless, and does so via the path of model-based thinking.

The strong influence of the models upon the direction of ideas in the young human being stems from the seeming realism of these conceptions. This does not just arise within the young human being as his own misconception (lacking the faculty to grasp the epistemological change of aspects) but lies in the very method of approach, in the atmosphere of the teacher. For it is true, the models are consciously being introduced as convention, i.e. as Nominalistic conceptual interconnections. In spite of that however they are chosen on the grounds of a possible further shaping and extension in the direction of “true” quantum mechanics. Out of this misconceived aim realism arises, which however cannot be maintained on closer scrutiny of the nature of quantum theory—as already shown.

Borrowing in this way from the supposed realism (which quantum mechanics has “proven”) on the part of the actually Nominalistic models is on the whole an ontological substitute of matter, and it is the effective device to bait the student’s existing need to unfold the world, in order to trap it in a mechanistic ideology—without most teachers being aware of this. Thereby the ideology outlined does not only arise, but at the same time promotes the belief that it is scientifically proven for good. As with every ideology, it is then felt to be progressive and liberating, fundamentally and in essence illuminating, and irrefutable for all times!

In spite of all this there might be the odd practical-minded teacher who still prefers the models for reasons of learning—economy. After all, as one author says, we are “forced to already introduce a usable atomistic model in the intermediate grades. For the enormous amount of facts which the beginner cannot possibly survey not only has to be organized but must also be ‘understood,’ i.e. mentally digested.”

A related argument is often raised: Model-based considerations today are the only way of working and thinking that links together the whole of chemistry and science. Any curriculum which bypasses this finds itself spiritually on another plane! This opinion can only be invalidated by developing a factual chemistry syllabus that can do without the models in, say, the four high school grades. This has now been done and has been tested in the classroom within a didactic research project.

It is to be shown in further practical application that it is possible to work and to learn with such an approach in an educationally purposeful way and benefiting the subject at the same time; and apart from this that the later transition to models and formulae will still lead to the specific aspects of chemistry in a sufficiently encompassing way. Then in the end the demands of education (as well as of the subject) would have the right balance. The opponents of any re-thinking in the higher classes which would therewith become necessary have to be told in the words of Wagenschein: “I can think of no reason why the schools should not only fail to encourage but even explicitly prevent any re-thinking, which after all is thinking based on facts.” The decision to pursue a phenomenological education on an epistemologically sound base (i.e. without plain phenomenalism on the one hand, and without animism on the other)—even if not fully developed—is the only thing that can be put against the deplored deficiencies in the naïve attitudes towards nature and science.

How can a late introduction of the models be realized today?

After the foregoing criticism of the early introduction of models, here is a glance at a possible late introduction of these theories, which, of course, are indispensable for the understanding of contemporary science.

Sketch of a curriculum in the sense of a comprehensive school ('Gesamtschule')

The concept of a syllabus in the sense of the thoughts outlined here, e.g. for chemistry (parts of physics are thereby also transformed and integrated), generally makes cuts in the volume of specialist teaching material—for the benefit of a penetration from the point of more mechanics, which otherwise is in most cases not offered and which includes demanding experiments. The whole of atomistic theory is introduced, even if late, but then on the basis not only of modern but of actually constituting conceptions of the wave-particle dualism. This tendency in the didactics of chemistry (from a purely specialist approach) also shows up elsewhere. The well-known quantum-chemist Preuss calls the confusion of rules and simple model-based descriptions ("electron-bowling") a first stage, which was useful (and partly still is) but which does not lay hold of the actual facts.

It is not the point of the approach followed here to declare the classic atomistic theory or the models usually used in teaching as being fundamentally questionable and to scrap them. What is the point is that the teacher introduce these model-based structures concurrently with the right forms of their conceivability—or at least to discuss this. Otherwise the conceptions of naive (and maybe even of didactic) materialism as it was deplored in the above, are being consolidated. The latter of course implies that the atomic structures be essentially within reach of the comfortably visual ideas of everyday or other scientific experience—the ideas of place, time, mass and occupation of space, as well as tangible identity. Such a misconception nowadays is always at hand considering popular literature. The atomic theory of earlier centuries also succumbed to it. This misconception can only be avoided if the atomic theory is developed not historically or in a positivistic triumphant way—"how marvelously far we've come"—but as it was from its epistemologically questionable other end.

The wave-particle-dualism of matter here is the basic conceptual formation. For the students, however, to gain such an understanding in an undogmatic way can only come about through important, if possible personally conducted experiments.

An appropriate experiment however, e.g. the diffraction and interference of electrons, is only comprehendible with a wide background-knowledge of physics—at its earliest probably in class 12. It seems neither possible nor educationally sensible to inject such specific preparatory knowledge earlier, say in class 9. For an important characteristic of atomic phenomena is the very fact that they are understood and have meaning not as isolated experimental statements but only at a later stage on the conceptual base of all the different parts of the whole of physics. Thereby advantage is taken of the fact (which is also a demand) that one teaches within the framework of a comprehensive school of at least 12 classes as in Waldorf school, i.e. where the students rarely leave before class 12.

Therefore, the task of waiting with model-based interpretations until say class 11 arises and today is widely felt to be an impossible one. To be able to do chemistry appropriate to the age up to this point, a new orientation and additional training of teachers becomes necessary; also in related subjects.

The position of this type of didactics in relation to a comprehensive school is yet to be examined. If the student's faculty of thinking and judgment can successfully be kindled by directly taking in the phenomena,* and if the students themselves can be made to feel that their mental capacities are thereby growing, then, for a start, all the theoretic, dogmatic ballast can be suppressed, which today—in form of the crude conceptions of the particle—is thrown at the children from all sides by the media. If therefore the syllabus in classes 8, 9 or 10 does not move within the superimposed awareness of the problem but instead, if in experiment it meets always anew a reality which at first is not systematized, then the promise of the comprehensive school can be fulfilled in this way—and only in this way: The student of the lower school can become active side by side with the student of the upper school in that he observes, describes, compares and in that he receives and reports on the further reaching implications, which are developed more with the student of the upper school—and both are making progress. It therefore is not so much the delaying of the models which makes up the syllabus of a comprehensive school, but rather that which is done in place of the models and which replaces them for a time.

* The term phenomenology (phenomenological) today is generally not used in the sense that is meant here, because it is not known. One will grasp what is meant here, when one gradually learns to differentiate between “phenomenal” and “phenomenological.” The following definition may be a first indication:

- A phenomenon (as is well known) is different from a perception (sense experience). It already is an integrating, differentiating, organizing comprehension (also condensation) of perceptions. It therefore has initially the character of a concept; without this it could not be experienced.

- Phenomenalism is a way of observation which does not go beyond merely finding and organizing (classifying, bringing into a system) of phenomena—that is, with tested rules and laws. The phenomena are thereby more outwardly accounted for within sterile categories (quantities) of space, time and movement.

Phenomenology on the other hand means to give a Logos, or meaning, to the phenomena. And that is not by way of taking recourse to metaphysics but through a free searching for coherent continuity. Thereby, not only the categories (quantities) which relate to measuring instructions, but all actually perceivable, through perceptions experiential qualities, are being worked. Open concepts are also included before they have saturated the experience through hasty definition. Only through this type of thinking can new questions arise and be put to the phenomena, and from the segmented observation which initially always prevailed, one moves away into the direction of a whole—not of the thing in itself, but of the width of interrelations.

Counter arguments

One could object that it is perfectly feasible to introduce the models in class 9 or earlier (furthermore, that one must do so—for the benefit of departing students), if only and at the same time one prevents them from turning into that ontological substitute of the world. I have tired to show in the first part of this article that in practice this can obviously not be achieved. For as soon as one deducts from the models conclusions that relate to specific facts, for the children they mean more than mere possibilities of combination. This “more” of course exists quite factually, but it can only be understood in the “right way,” (i.e. non materialistically through quantum mechanics). An early introduction of the models today leads to the described misconception also because the popular scientific consciousness which of course forms nearly all spheres of life is deeply penetrated by it. The students are preprogrammed for the misconception! The wish to start with the models, particularly carefully but still earlier than what is held here, seems unreal because the young human being’s thinking is not free but already occupied. Before anything else it needs to be made naturally impartial by a carefully aimed counter-move. The aim towards treating background questions of scientific method and model-based thinking first of all needs to build on a many-sided base of departure; one must, so to speak, catch up with and practice original and independent observation of nature. That is the most important task of the early years—extensive, time-consuming and with always new demands on the creativity of the teacher.

Also any subsequent radical questioning of the model-based view of nature hardly frees oneself from the latter (as I have tried to show). For the inner strength of a question, the motivation to bear its tension productively, springs from the strong connection with something that expresses itself in terms of “on the one hand—on the other hand”; it springs from becoming aware of one’s own living within initially conflicting relations. If however one lives monotonously from childhood on within the “scientific world conception” described at the outset, then, it is true, one can question it at one stage or other, but such questioning will only become serious once one has also come to know, to experience, to consider the phenomena outside of the patterns of interpretation by the different branches of science. Even the best subsequent philosophical enquiry into the modern scientific method of acquiring knowledge surely cannot lead the student to seek in a way that is critical of the methods employed, unless another way of working, that is not yet so strongly reduced to quantitative and formally generalizing aspects, has actually been practiced for a number of years bearing fruit in the development of the student's thinking.

Final remark

It is the currently prevalent and encouraged motto of specialist teaching, particularly of chemistry, to see in the premature introduction and emphasis on model-based thinking a measure for the advancement and efficiency of every teaching methodology. The intention of our considerations is to point out that from a point of view from outside the particular technical specialty, e.g. in the eyes of the adult layman, this must appear questionable. It was shown that a concept differing greatly from the conventional, which arose out of Rudolf Steiner's theory of knowledge and out of developments of Waldorf education, is precisely not based on what one might fear after only initial contact:

1. that modern changes in the different branches of science and in didactics are being rejected;
2. that world conceptual presumptions flow as contents into lessons;
3. that a small student elite (Waldorf pupils) should be spared the coldness and somberness of contemporary natural science.

Much rather the endeavor is:

1. to build up in the first part of secondary school a true syllabus of a "comprehensive school" (without outer differentiation) that also includes the intellectually slow students and weak learners;
2. in the second part of secondary school to make fundamental use of the new concept of Beingness of modern physics, and not to work against such a concept in the previous stages;
3. to exercise various aspects of reality penetrating more deeply to the core of things, so that the students remain independent in the face of all world conceptions, in particular the "natural scientific worldview."

Insofar as some subject matter is sacrificed for a more general, philosophical aim, modern model-based theories are essential. For it is just these which demonstrate to the student more and more markedly the contrast, say, to phenomenological thinking. Only in this way can the recognition be won that scientific conceptualizations are a free human creation.

Education is a basic process—finding ways to be human.

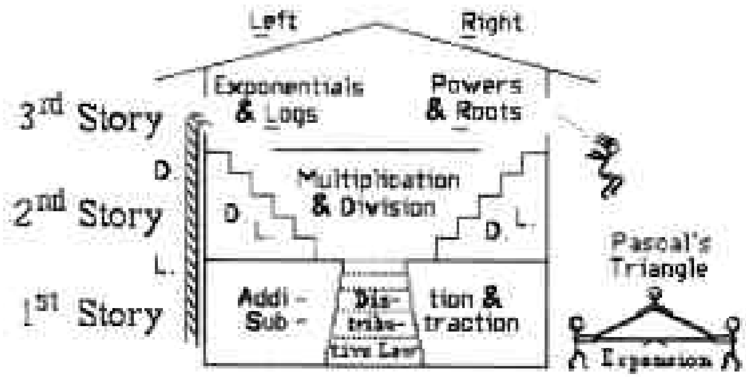
— Bill Stonebarger

The House of Arithmetic

by

Stephen Eberhart

This is an excerpt from a wonderful booklet by Steven Eberhart, “Mathematics Through the Liberal Arts” *used in his courses at California State University, Northridge. It is another look at the ideas on the human dimension of the “nine processes” discussed at the Math-Skills workshop in February, 2002 (see the AWSNA Computer Colloquium proceedings).*



The first floor or story is usually thought of as having only two operations, addition and subtraction, but the latter occurs under two distinct conditions and uses two distinct keys on calculators. To evaluate a + b = x, one simply adds a + b; and since a + b = b + a, it doesn’t matter in which order one adds them, as expressed by the way such sums are written vertically in elementary school as $\begin{array}{r} a \\ \underline{+b} \end{array}$. The addition is said to be *commutative.*

To solve a + x = c for x, one must subtract off or deduct a from the left on both sides of the equation to obtain x = –a + c (as in writing a $15 check against a $100 bank account). The operation of negation (denoted by ± or CHS [change sign] key on calculators) works on a single number, changing a to –a, interchanging positive and negative signs.

To solve x + b = c for x, one must subtract off the b from the right on both sides of the equation to obtain x = c – b or the difference between c and b (like thinking one still had $100 in one’s account, getting a statement for $85, and having to reconcile it by remembering the $15 check). This is the proper “minus” (though negatives are often read as minuses), operating between two numbers.

Neither form of subtraction is commutative, since c – b = –(b – c). They are negatives of one another.

As a stair between first and second stories, we have the distributive law a(b + c) = ab + ac and (c + b)a = ca + ba, equivalent by the commutivity of both addition and multiplication. For, just as with addition, we first meet multiplication in elementary school expressed in vertical columns as $\begin{array}{r} a \\ \underline{\times\, b} \end{array}$ in which there is no distinction between left or right, ab = a • b or a x b having same value as ba = b • a or b x a.

To solve ax = c for x, one must divide both sides of equation by a on the left, obtaining $x = \frac{1}{a} \cdot c$ or the result of cutting or dividing up c into a many pieces. The key that turns single numbers such as a into their reciprocals $\frac{1}{a}$ is called $\frac{1}{x}$ or x^{-1} on most calculators.

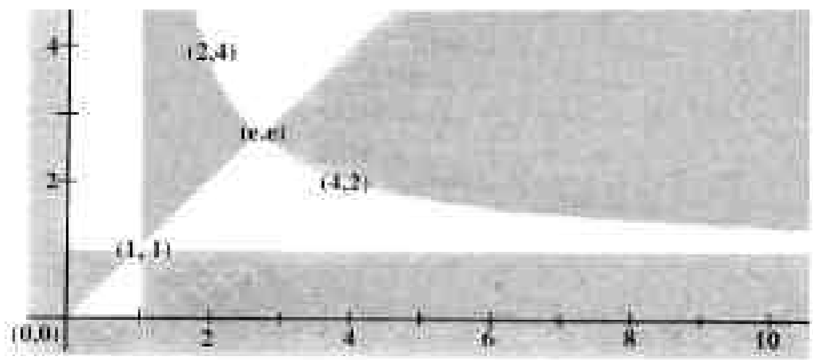
To solve xb = c for x, we must divide both sides of the equation by b on the right, obtaining $x = c \cdot \frac{1}{b}$ keyed in as either c ÷ b or c/b on most calculators, a process that evaluates the quotient or ratio of two numbers. As with subtraction, it is not commutative; $c/b = (b/c)^{-1}$. They are reciprocals of one another.

[A word of warning: Be careful not to write expressions such as 1/2x when you mean $\frac{1}{2}$ x, for 1/2x is taken by convention to mean 1 ÷ 2x, hence $\frac{1}{2x}$, while $\frac{1}{2}$ x by convention means $\frac{1}{2} \cdot$ x , hence $\frac{x}{2}$ — not the same thing!]

There are two staircases between the second and third stories: One seems like a form of associative law, but it is not. Inspecting $a^{bc} = a^{(bc)} = (a^b)^c$ carefully shows a mixture of power and product processes at work, as opposed to the pure addition in associativity of a + (b + c) = (a + b) + c and pure multiplication in associativity of a(bc) = (ab)c. [Another word of warning: $(a^b)^c \neq a^{b^c}$, so it is good handwriting practice to keep the two exponents b and c on same level, suggesting the true $(a^b)^c = a^{bc}$.]

The other is a true distributive law, $(ab)^c = a^c b^c$, comparable to (a+b)c ac+bc, but from one side only [there is no ${}^c(ba)$ comparable to c(b+a) = cb+ca].

When we reach the third story we meet full non-commutivity, for $a^b \neq b^a$. $2^4 = 4^2$ is the only solution to $x^y = y^x$ in integers y ≠ x; the curve of other nontrivial solutions crosses the straight line of trivial solutions y = x, at point (e,e).



[For other ways in which the number e = 2.71828. . . arises naturally in this context, see any good math text. In particular, note that the abbreviation ln or ℓn is for *logarithmus naturalis* in Latin word order; do not miswrite it as In.]

The symbol b^a can be read several ways. Usually we say "b to the a^{th} power," and when the variable x is in the base then x^a is definitely a *power* function (reading x^2 as "x squared" and x^3 as "x cubed," etc.). But when the variable is in the exponent then b^x is properly regarded as an *exponential* function, also written as $\exp_b x$ (read as "exponential of x, base b"). Since $a^b \neq b^a$, they have separate inverse functions (usually found above their respective keys on your calculator).

To solve $x^a = c$, we must do the opposite of an a^{th} power and take an a^{th} *root*, obtaining $x = \sqrt[3]{c}$ or $c^{1/a}$.

But to solve $b^x = c$, we must do the opposite of an exponential base b and take a *logarithm* base b, obtaining $x = \log_b c$. To evaluate this, we use the laws of logarithms (which are simply the laws of exponents, a logarithm being an exponent that has been solved for or isolated), turning $b^x = c$ into $\log(b^x) = \log c$, recognizing that the left side is short for $\log(b^x) = \log(b \cdot b \cdot b \cdot ...)$ with x factors, hence equal to logb+logb+logb+… with x terms, hence equal to x•logb, whence $b^x = c$ is solved by setting x•logb = logc and obtaining x = logc/logb, or ratio of two logarithms to any convenient base, e or 10. (The word *logarithmos* means "ratio number" in Greek.) For example,

$$2^x = 3 \quad \text{for } x = 1n3/\ln 2 = \log_{10} 3/\log_{10} 2 \approx 1.58496.$$

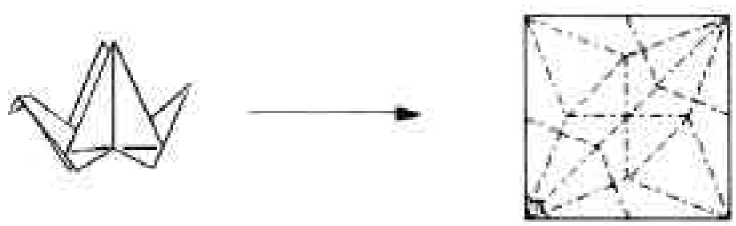
On the left, finally, we have have $a^b \cdot a^c = a^{b+c}$ shown as a ladder spanning all three stories, whereas on the right we have $(c+b)^a$ or $(x+y)^n$ expandable by use of n^{th} row of Pascal or Chinese triangle when n is a natural number.

Web Gems

The web site at the University of California/Berkeley listed below is a great source for classic demonstration setups that are not readily found in ordinary textbooks. I especially liked Oliver Lodge's early radio transmitter (simple transformer) demonstration. Also included are demonstrations on: mechanics, waves, properties of heat and matter, electricity and magnetism, optics, astronomy and perception, demo drawings and modern and contemporary physics.

http://mip.berkeley.edu/physics/physics.html+

Origami Mathematics



This article is an attempt to provide information on the mathematics of paper folding. Anyone who has practiced origami has probably, at one time or another unfolded an origami model and marveled at the intricate crease pattern which forms the "blueprint" of the fold. Clearly there are some rules at play in these collection of creases. Clearly there is an **origami geometry** at work when paper is folded.

Such geometry, this mathematics of origami, has been studied extensively by origamists, mathematicians, scientists and artists. The Italian-Japanese mathematician I Humiaki I Huzita has formulated a list of axioms to **define origami** geometrically. Physicist Jun Maekawa has discovered some fundamental theorems about origami and used them to design origami models of surprising elegance. Mathematician Toshikazu Kawasaki has a number of origami theorems to his name and has even generalized some of them to describe paper folding in higher dimensions. (Origami in the fourth dimension!) Robert Lang of California has developed an ingenious way to algorithmatize the origami design process, using a computer to help him invent models of amazing complexity. Educator Shuzo Fujimoto and artist Chris Palmer have discovered amazing parallels between origami and tessellations. And an enormous number of teachers have been developing ways to use origami to teach concepts in math, chemistry, physics and architecture.

Go to the web site below:

http://web.merrimack.edu/~thull/OrigamiMath.html

Understanding Parabolic Reflectors Through Paper-Folding

by
David Chandler
Science/Mathematics Division, Porterville College,
Porterville, CA

The definition of a parabola, as presented in math classes, is the set of all points in a plane equidistant from a given line (called the directrix) and a given point not on that line (called the focus). The physical significance of the focus is clear, but I had never had an intuitive appreciation for the directrix. While my physics class was doing a ripple tank lab with parabolic reflectors, the role of the directrix became clear to me in a new way. As a plane wave strikes the interior of a parabolic barrier, it is transformed into a circular wave converging toward the focus. The entire wave front reaches the focus at the same time, and therefore in phase (a fact that is critical for astronomical telescopes to focus starlight). If the parabolic barrier were absent, the plane wave would proceed to the directrix in the same amount of time. In other words, the reflection at the parabola can be seen as transforming, or "folding," the directrix into the focus.

This suggested to me that one could construct a parabola by literally folding a set of points from the directrix onto the focus.[1] When I tried this, I found that each crease in the paper is a tangent line to the parabola with the light ray reflecting at equal angles. (The fact that the creases are actually tangent lines is easily provable without calculus, as will be shown below.[2]) In making the folds, one actually "enacts" the definition of a parabola. One is locating a set of points equidistant from the directrix and the focus.

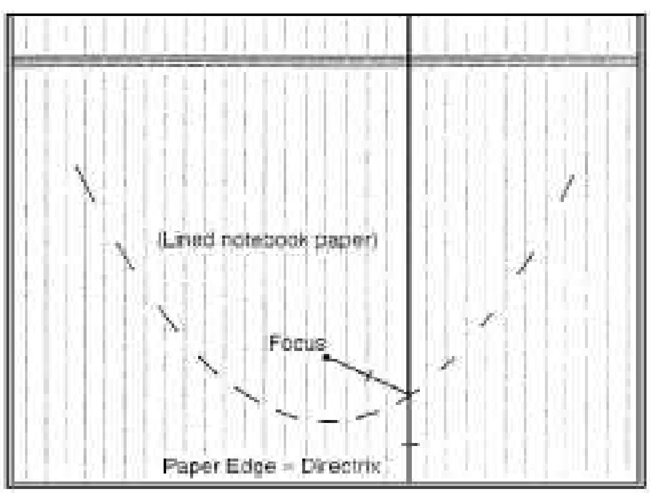


Fig. 1. Using lined notebook paper, with the lines running vertically, consider the lines to represent incoming light rays. Choose any point on the paper to be the focus. The directrix is the bottom edge of the paper. Fold each point where a light ray meets the directrix up to the focus and mark where the crease intersects the light ray. The points of intersection are equidistant from the focus and directrix, so they form a parabola by definition.

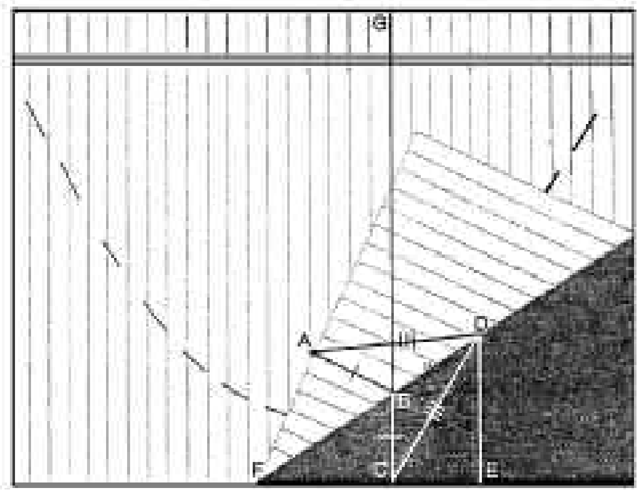


Fig. 2. Only one point on each crease lies on the parabola. All other points can be shown to be closer to the directrix than the focus. Therefore, the crease is a true tangent line. Furthermore, the incoming light ray reflects from this line to the focus at equal angles which confirms the focusing property of a parabola.

Showing that the ray reflects at equal angles at the crease is the simplest part of the proof. Note in Fig. 2 that angles ABF and FBC are equal because in folding the paper, one is superimposed on the other. Angles FBC and DBG are equal because they are vertical angles. Thus angles ABF and DBG are equal as well. This verifies that a mirror placed along the crease would reflect an incoming ray to the focus. It remains to be shown that the crease is actually tangent to the parabola at the point of reflection. Consider any point D on the crease, other than point B. We will show that D is closer to the directrix than the focus, which implies that any point along the crease other than B is outside the parabola; therefore, the crease touches the parabola at only one point. Note in Fig. 2 that BD is shared between the two triangles, ABD and CBD, and, upon folding, C maps to A. Therefore, AB = CB and AD = CD. Since CD is the hypotenuse of CDE, DE is shorter than CD or AD, so D is closer to the directrix than to the focus, which concludes the proof. When I ask my students out of the blue to define a parabola, they usually say $y = x^2$, or something similar. It is a rare student who remembers the directrix-focus definition, and even then it is generally seen as a mathematical abstraction devoid of intuitive significance.This paper-folding exercise reinforces the actual definition of a parabola, making the definition just as concrete as the pins and string construction of the ellipse. As a bonus, the activity ties the definition of the parabola to its reflection property without calculus.

An ellipse is the set of points in the plane for which the sum of the distances to two focal points is a constant. A hyperbola is the set of points in the plane for which the difference of the distances to two focal points is a constant. Both of these curves have focal properties as well. A circular wave expanding from one focus of an ellipse will converge in phase to the other focus. Less well known is the fact that a wave expanding from one focus of a hyperbola will be transformed upon reflection from either branch of the hyperbola to an expanding circular wave centered on the other focus. Reflection properties of all three conics are used in optical designs, and all three conics can be constructed by paper folding. Furthermore, the creases in each case are tangent lines that illuminate the reflection properties of these curves. With the construction of the parabola as a guide, the construction of the other two conics is left as an exercise for the reader.

References

1. Although I discovered on my own this construction of a parabola as described above, I am not the first to construct a parabola by paper folding. I have since found there is significant literature on geometric constructions through paper folding. For an extensive bibliography of mathematical origami, see
   http://web.merrimack.edu/thull/oribib.html.
2. This proof is similar to one suggested by G.D. Chakerian, Calvin D. Crabill, and Sherman K Stein in their remarkable text *Geometry: A Guided Inquiry* (Morton, 1998).

— Printed in *The Physics Teacher,* Vol. 39, January 2001.

Outdoor Education Initiative Holds Third Gathering

The Anthroposophical Initiative for Outdoor Education (AIOE) held its third gathering in July of this past summer. This group has formed to help foster connections to the Earth and to Spirit through nature-based experiential adventure and activities in the wilderness. Members of the initiative are developing programs to provide Outdoor Education experiences in the Waldorf schools and within Anthroposophical circles and beyond, for both youth and adults.

The gathering in July was a six-day outing, which included a four-day river trip on the Rio Chama in northern New Mexico. The group was able to further its work on many levels while adventuring through the pristine wilderness of the 1500 foot deep, forested canyon of the wild and scenic designated Chama River.

The Initiative was able to actualize an earlier-stated goal of including young adults with the inclusion of three Waldorf graduates on the Chama River trip. These three young adults, who are themselves involved with wilderness work, were able to greatly aid the group in its examination of the needs of youth and the potential of wilderness/nature experiences to meet those needs. These Waldorf graduates have joined the initiative and the (AIOE) is now even more committed to inviting young adults into the initiative.

Through a series of working sessions while on the river trip, the Initiative group was able to achieve the following

- A furthering of the group process of building connections among ourselves
- A continued examination of the needs of youth
- The beginning of the process of exploring core values of the group
- The creation of a mandate group regarding reports and publications
- Reports given on the various Outdoor Education projects that are being developed by initiative members.
- The agreement to list the AIOE in the Initiative Directory of the Anthroposophical Society of America
- The decision to form a Subject/Interest group within the Anthroposophical Society

This last item had been in the group's discussions since the group's inception, and the Initiative has plans to recognize this "deed" ceremonially at its next gathering.

AIOE members are currently developing the following projects, and reports were given concerning each of these projects:

- Expansion of the Society-sponsored *Challenge Program* led by Maggie Mahle and David Sloan
- The development of the Exploration Program led by Lisl Hofer, based out of the Kimberton Waldorf School
- The forming of a Women's Wilderness trip led by Maggie Mahle
- The creation of a Southwestern Outdoor Education Center serving Waldorf schools and adults led by Craig Rubens and Karl Johnson, arising out of a collaborative relationship with Deer Hill Expeditions near Durango, Colorado.

Each of these projects seeks to provide wilderness experiences in light of Anthroposophy for youth and adults seperately, and in some cases, for youth and adults together.

The group was also able to reach these additional decisions:

- A commitment to further examination of the needs of youth, with young adults and adolescents being involved in the process
- A commitment to continue the process of exploring core values of the Initiative
- The decision to begin the nonprofit organization status process

• The agreement to continue the Initiative's outreach efforts to network with others working out of this Waldorf/Anthroposophy/Wilderness impulse

• The decision to hold a fourth AIOE gathering in Algonquin Provincial Park, Ontario, Canada, in mid-February, 2002.

The AIOE is also now increasing its funding research, and individual projects are also exploring grants and alternative funding possibilities.

There is particular interest among members of the group to develop programs that would broaden the Waldorf/Wilderness connection to include cross-cultural experiences between Waldorf students and Native American youth. The interaction between Waldorf students and "the world," providing cross-cultural experiences and the opportunity for service, is a project that will continue to be researched over this coming year.

Finally, a report on the forming of the AIOE and various wilderness-based adventure and service projects that might serve the Waldorf high schools was given by AIOE member Lisl Hofer at the High School Research Conference in October 2001.

This third gathering of the AIOE was a particularly rich one, and the natural beauty of the northern New Mexico canyon country was a profound inspiration for all of us personally and for the work that is unfolding between wilderness and Anthroposophy.

On the last day, just a few miles downriver from the Christ in the Desert monastery, past which we had floated in our boats the day before, we enacted the Spatial Dynamics exercise called "The Cross" on a rock outcropping jutting over a bend of the Chama River, and we re-dedicated ourselves to our work by reciting the mission statement of the Initiative:

Working out of Anthroposophy, and the striving spirit of our times,
we are committed to working together
to further the development of a healing relationship between
Wilderness, Nature, and the Human Being.

Interested parties are invited to contact the Anthroposophical Initiative for Outdoor Education in writing at 880 Union Street, Boulder, CO 80304.

Karl David Johnson
Santa Fe, New Mexico
for the
Anthroposophical Initiative for Outdoor Education

The
Anthroposophical Initiative
for
Outdoor Education

— AIOE —

Who are we? What are we? How are we? Where are we?
When are we?

We are a group of people inspired by the healing forces of
Nature/Wilderness.

We are a group dedicated to furthering the development of
connections to
Earth, Self, Others, and Spirit.

We are leaders, we are teachers, we are students.
We are wilderness guides,
We are social developmentalists,
We are mavericks.
We are adventurers, we are sojourners,
We are mountaineers, we are boaters, we are climbers,
We are skiers and snowshoers,
We are hikers, we are backpackers.

We are "Waldorfians."
We are students of Anthroposophy.
We are Anthroposophists.

We are creative, dynamic, reflective,
imaginative, mindful, thorough,
organized, spontaneous,
adventurous,
safe,
fun.
We are people wishing to further an impulse.
We are people developing programs.
We talk, we listen, we flow, we adventure,
We play, we work,
We create.
We are East, we are West, we are North, we are South,
We are wilderness bound.
We are past and future, we are Now,
We are Summer, Winter, Aututmn, Spring.
We are soon...
We bear the "call of the wild."
Do you?

Notes from the Classroom

Sixth Grade Acoustics

Emphasis was placed on:

a) investigation through intensive quiet listening

b) accurate observation and concise description of phenomena we experienced via experiments

c) calling forth of amazement and wonder in the face of beautiful and sometimes entirely unexpected experiences

d) active student involvement with many experiments which they could carry out on their own. A wealth of these can be dug out of generally available resource books

No emphasis was given to any theoretical explanations which would only lead the children into speculations of a more abstract nature. This is, of course, the danger that lurks in all popular books on acoustics and must be properly recognized.

As a guide in working with these 11- and 12- year-olds, one might apply such a criterion as this: let the head understand that which is experienced through the senses and felt in the soul.

Now to a few experiments which proved of particular value:

1) A set of tubular bells which a handyman on the faculty can construct out of galvanized steel or duraluminium pipes which are tuned with a hacksaw and properly suspended.
   a) How long can a tone ring?
   b) Can you hear the fundamental and the overtones?
   c) Feel the strong and sustained vibrations!
   d) Discover areas of greatest and least vibration.
   e) How to strike the pipes to get the most beautiful tones?

2) A large set of bowls of glass, china and hard metal to be played with a felt mallet. Then slip in, unnoticed, a bowl of pewter or of similar, deceptively hard-looking material. The resulting “thud” is most amazing and leads into further investigation of what shapes and materials give rise to ringing sounds, grating sounds, and dull sounds.

3) A set of tuning forks , including one or two low tones. Excellent for listening; for seeing and feeling the vibrations; for making the vibrations visible when the vibrating ends are dipped into water; for experiencing resonance when placed against resonant bodies; for tuning other instruments.

4) Only after we had thoroughly experienced the free vibration of tinging, vibrating bodies did we go over to discover that when one blows the recorder the instrument doesn’t vibrate. With a tenor recorder one can, however, feel a vibration at the closed fingerholes. Thus the idea of vibration of the air (here a column of air) is experientially established. These vibrations are maintained by blowing.

5) Sound and vibrations always appear together, except when I sing a tune in my mind. Any further explanations are strictly up to the teacher’s conscience and may not be necessary at all. Maybe we are surrounded by a world of sounds which make themselves audible whenever something vibrates.

6) A “gunshot” (2 hardwood boards hinged together) or a hammer and plate of iron are excellent in order to experience time lapse over a long distance. This leads to a most entertaining gadget: the garden hose telephone. just speak a humorous directive into one end of the hose inside the classroom and watch the receiving party 100 feet out in the playground carry out the action. Amazing! With a shorter hose and a funnel you can whisper secrets to your friend in the classroom which no one else can hear.

7) A monochord, or 2-stringed sonometer, preferably a long one. If the string is 180 units long, then the subdivisions for the series of overtones and the tones within the first octave fall on whole numbers. Our string was 180 cm. long. We began our study by searching for the nodes. Set the string vibrating and touched it over and over again in different places until we suddenly heard a distinct, ringing overtone while touching the string.
The focusing demanded careful listening. (The seventh was hard to find.) Each node was marked on the resonance box. Finally we were able to play all 8 tones of the octave and to experience the intervals. Then after several musical experiences, we measured the distances and established the proportions:

	Tonic,	Second,	Minor Third,	Major Third,	Fourth,	Fifth,	Sixth,	Seventh,	Octave
	180cm.	160	150	144	135	120	108	96	90
expressed as proportion		160/180	150/180	144/180	135/180	120/180	108/180	96/180	90/180
reduced to lowest terms	1	8/9	5/6	4/5	3/4	2/3	3/5	8/15	1/2

One can ponder the qualitative aspect of these proportions and their corresponding intervals. For example: listen to the fifth and think of the proportion 2/3. Then listen by way of contrast to the seventh. In all of this the children can experience a cosmic harmony manifesting itself in the natural division of the single string: a harmony which lives on in our music (but which we can also degrade.)

8) For our Chladni tone forms we couldn’t get a brass plate, but a homemade square plate of galvanized sheet metal (heavy gauge) sprinkled with salt worked well.

9) Children were encouraged to make their own instruments: bottle and wineglass organs, washtub or gallon-can string basses, shoebox guitars, etc. Neat and artistic workbooks were expected.

One word of caution for the teacher: Leave yourself plenty of time to experiment, play, and experience the phenomena well in advance. Immerse yourself in the manifoldness of the phenomena.

— Helmut Krause
Toronto Waldorf School
From the *Waldorf Clearing House Newsletter*
Spring 1975

Sixth Grade Kaleidoscopes

Making kaleidoscopes in conjunction with our study of light this year was a project which the students enjoyed. Materials for each kaleidoscope cost about 55 cents.

Materials: 3 mirrors, 5-1/2" x 1-3/8" (purchased from a scientific supply house for about 15 cents each)

- 1 long piece of 1-5/8" wooden lattice stripping (available at any lumber yard) cut into 5-1/2" lengths.

- 1 piece clear vinyl plastic and 1 piece of cloudy or smoky vinyl plastic. These should have the flexibility of a plastic playing card; I got these from a plastics company listed in the Yellow Pages.

- Masking tape

- Strong, inexpensive glue—I used panel adhesive in a caulking gun

- Scotch tape

- Assortment of colored glass chips, the smaller the better.

Directions:

1 . Place the mirrors lengthwise making a solid figure that looks like a 3-faced prism. The ends should form an equilateral triangle, as shown, with the reflecting side on the inside. Make sure the ends overlap as shown.

2. Keeping your triangle perfect, wrap it firmly with masking tape, so that the sides stay quite unmoving.

3. Take the plastic. Hold the mirrors perpendicular to the plastic, and trace the outline of the triangle on both sheets of plastic. Cut out the triangles. You should have one of clear and one of cloudy plastic, the approximate size of your mirror triangle.

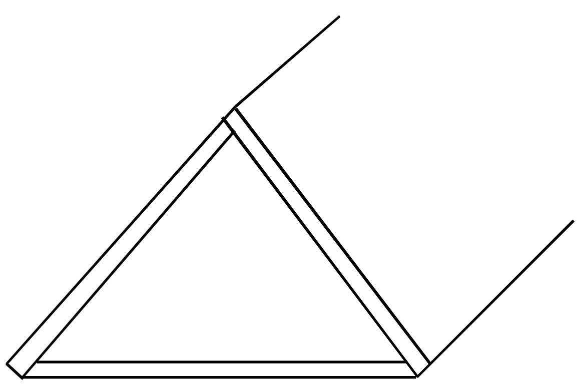
4. Hold one plastic triangle over the other so that all corners meet. The clear plastic should be closest to you. Scotch tape two of the sides together, leaving one side open. You should now have a triangular pouch formed by the two plastic triangles, with the clear triangle still nearest you.

5. Into the open end put small pieces of colored glass, choosing your colors as you will. Do not pack the pouch too tightly; the chips should be able to move around freely. Seal the third side with Scotch tape.

6. Place the pouch at one end of the mirror triangle, with the clear plastic on the inside, and tape it into place.

7. Glue three strips of wood onto the three outer faces of the mirrors. The wood may then be stained, painted, or decorated ad lib.

— Ronald Schneebaum,
Garden City Waldorf School
From the *Waldorf Clearing House Newsletter*
Fall 1972



All the dark there is can't put out
the light of a candle.

— Anonymous

TEACHING IDEAS

To introduce the Industrial Revolution, a hand-turned flour mill (such as the Corona Grain Mill of the Quaker City Mill) was brought into the class with a bag of whole grains (wheat). Each child sorted a handful or two of grain, eliminating any foreign matter; each then had a turn grinding the grain to flour. We tried to establish a quiet mood so that the children could be brought to an appreciation of the importance of the miller in earlier periods of history. The experience gave them a chance to see the purpose of using the steam engine and other power sources to replace manual labor. A discussion of the pros and cons of the Industrial Revolution and its side effects followed. The collected flour was given to the Kindergarten for the baking of bread—a treat for all.

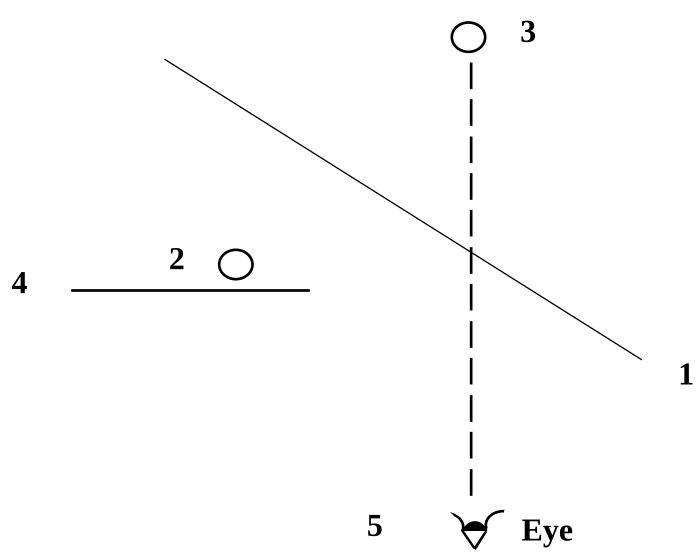
Ed Hill,
Kimberton Waldorf School
From the *Waldorf Clearing House Newsletter*
Winter 1971-72

Tricks with mirrors

Materials:

a) A glass pane (1) , a candle (2), and a glass of water can be arranged so that the candle seems to burn inside the glass of water. (Of course it is the mirror image which performs the feat.)

If the real candle is hidden by a shield of cardboard, a door, or something similar (4) from the viewer (5) , the sense of magic is further enhanced. Have some lights on in the room so that the light of the real candle behind the shield is not noticed.



b) Two mirrors are taped together on one edge. Place them in front of you on a table adjusting their angle to each other to 90°. Sit with your nose right in front of the right angle. You will now see your face the way others see it, not as you are used to seeing it in a mirror. If you blink your left eye, you will see this act performed by the eye on the opposite side of the mirror. It is not hard, even for 6th grade students, to understand and explain how the image of the left side of your face is reflected onto the second mirror and only then comes back to you, now on the right side.

— Gerhard Bedding
From the *Waldorf Clearing House Newsletter*
Winter 1971-72

Crystal Radio Lab

Based on versions from Sacramento Waldorf High School by John Petering and Miko Bojarski

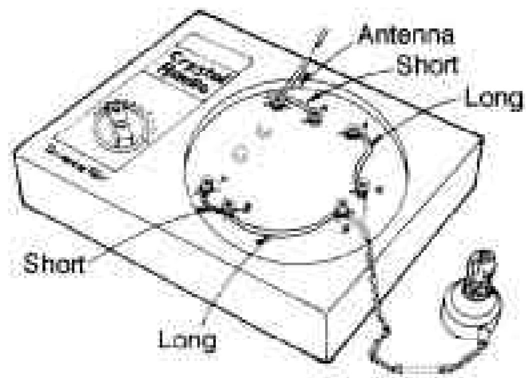
Purpose:
To build a working amplified crystal radio. To understand how a crystal radio receives the signal.

MATERIALS:

Crystal radio kit (ex: #MX901 distributed by Elenco, or #990-0252 from RadioShack.com), antenna wire, ground wire with alligator clip, earphone, 386 op amp IC, 10 uF electrolytic capacitor, 220 uF electrolytic capacitor, 10 KΩ variable resistor, 8 S2 speaker, breadboard, hook-up wire, 9 volt battery, battery clip.

PROCEDURE:

A. Remove the crystal radio from its box and verify that the proper connections have been made. The connections will be made either on top of the radio or underneath it.



1) Terminals 1 and 2 should be connected.
2) Terminals 3 and 4 should be connected.
3) Terminals 7 and 8 should be connected.
4) Terminals 8 and 9 should be connected.
5) The long tab on the tuning capacitor should be connected to terminal 6; The short tab on the tuning capacitor should be connected to terminal 7.
6) The germanium diode should be bridging terminals 2 and 3.
7) The black wire on the coil should go to terminal 2, the yellow wire to terminal 5, the white wire to terminal 6. the green wire to terminal 8.

B. There should be two coils of wire in the box. Use the one with the alligator clip as the earth ground wire. Attach the bare end to terminal 8 and clip the other end to a faucet.

DANGER: DO NOT STICK THE GROUND IN AN ELECTRIC SOCKET.

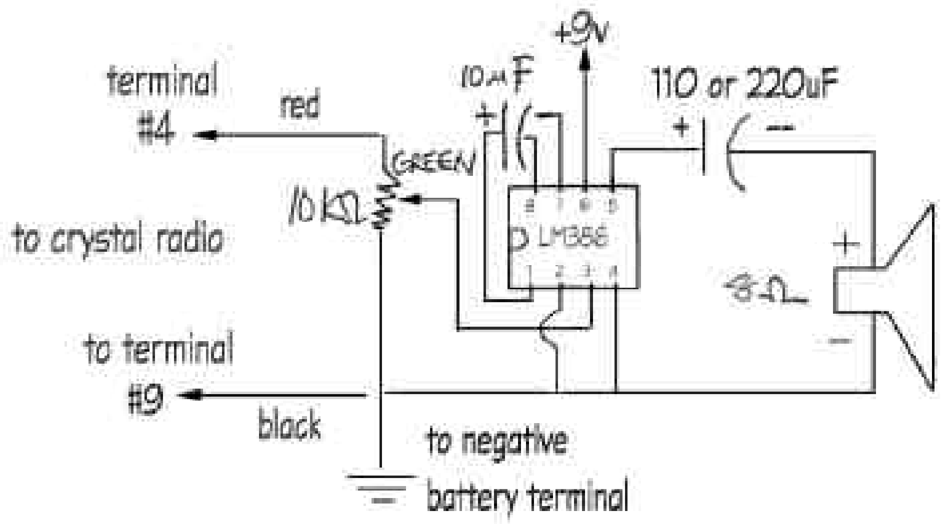
C. Use the longer coil of wire as your antenna. Attach it to terminal 1 and lay it out horizontally on the desk top.

D. Attach the earphone to terminals 4 and 9. Place the earphone in your ear and listen while turning the “tuning” knob. Can you hear a radio station? (try settings near #8, for local AM 1530kHz).

AMPLIFICATION

E. Breadboard the following amplifier circuit. Carefully seat the LM 386 audio amp chip in the breadboard; make sure all 8 pins are in sockets and the chip notch is on the left.

F: Attach the inputs on your amplifier to terminals 4 and 9 of your crystal radio; turn the knob on the variable capacitor; and adjust the 10 KΩ variable resistor volume control. How well does your amplifier work?



G. Observations:

1) When you are listening to your un-amplified crystal radio through the earphone, you are not using any batteries to power the circuit. The radio is working "for free."

   Where does the energy come from to run the radio?

   The weak magnetic field of the distant station causes a weak current in the antenna coil;
the LC circuit formed by the tuning capacitor (C) and the antenna coil (L)
allows only one radio station's carrier wave at a time to enter your radio.

2) Name the different radio stations you could hear on your crystal radio.

   We could hear 1530 KFBK News/Talk 10kW nearby.

3) When you hold terminal 1 with your fingers and add your body to the circuit, does reception improve?
   Yes, a bit, although holding the end of the "short" antenna improved the signal noticeably.

4) Does changing the position of the antenna improve the reception? If so, how?

   The best is horizontal, but extended to its maximum length.

5) Name the components a crystal radio needs to operate?

   Antenna coil—receives the magnetic radio wave, induced current
   Tuning capacitor—sets resonant frequency of the LC tuning circuit
   Crystal diode—gets rid of high-frequency carrier wave to ground, passes audio signal on
   Extra—audio signal amplifier, earphones or amplifier

6) Explain what it means to "tune" a radio to a station? What happens in the circuit when you vary the capacitance of the variable capacitor in order to bring in a station more clearly?

   The capacitor will determine the resonant frequency of the "tuning LC circuit," which
   allows only a certain frequency to be active in the tuning circuit.

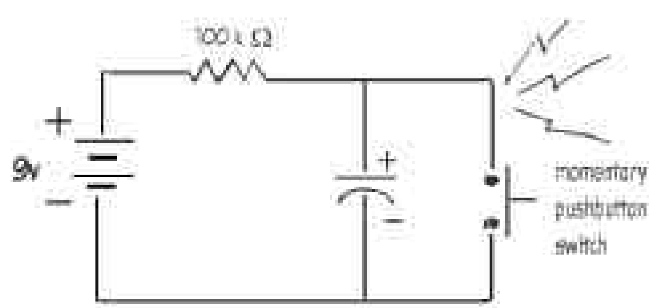
7) Why did you need an amplifier in order to hear your crystal radio through a speaker? Why couldn't you just hook up the crystal radio directly to the speaker?

   The signal was so weak that it must be amplified to be audible in the output earphone/speaker.

H. Keep your radio assembled. Use another breadboard to wire the following broadband RF pulse transmitter circuit. The resistor avoids a direct short circuit across the battery. Instead the 10 uF capacitor is shorted by discharging through the switch after being charged through the resistor.

I. Place the transmitter next to your radio and press the momentary push-button switch. You should hear a distinct "pop" on your radio.

   About how far away could you take the transmitter and still hear the "pop" on your radio?



J. Disassemble your amplifier and transmitter. Return the parts to their proper places. Coil your antenna and ground wires and carefully return the crystal radio to its box. Hand in your lab to the instructor.

Notes:

- If you live in a city, you might be able to receive several stations.
- If you do not live near a radio station, you might need an outside antenna, 35 to 85 feet (10 to 25 m) long, connected to terminal 5.
- A complete outdoor antenna kit is available at your local Radio Shack Store.
- If your radio does not receive stations well, try connecting the antenna wire to terminal 6 instead of terminal 1 or
- If reception is still poor, change the antenna coil connection as follows:

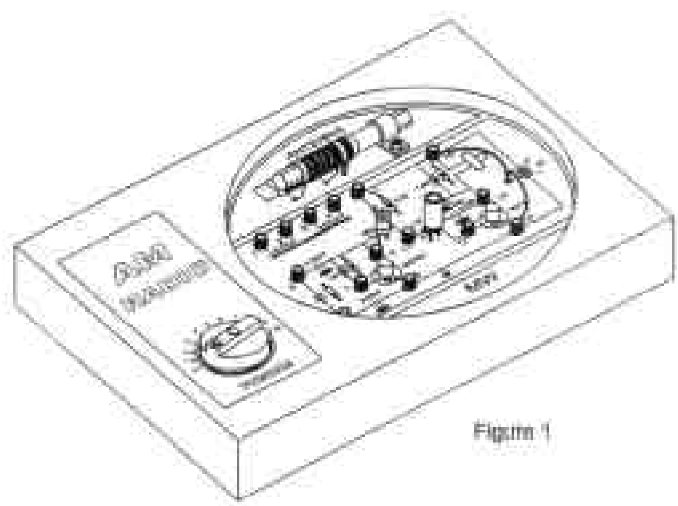
  White wire from terminal 6 to terminal 2

  Black wire from terminal 2 to terminal 6

Electronic Radio

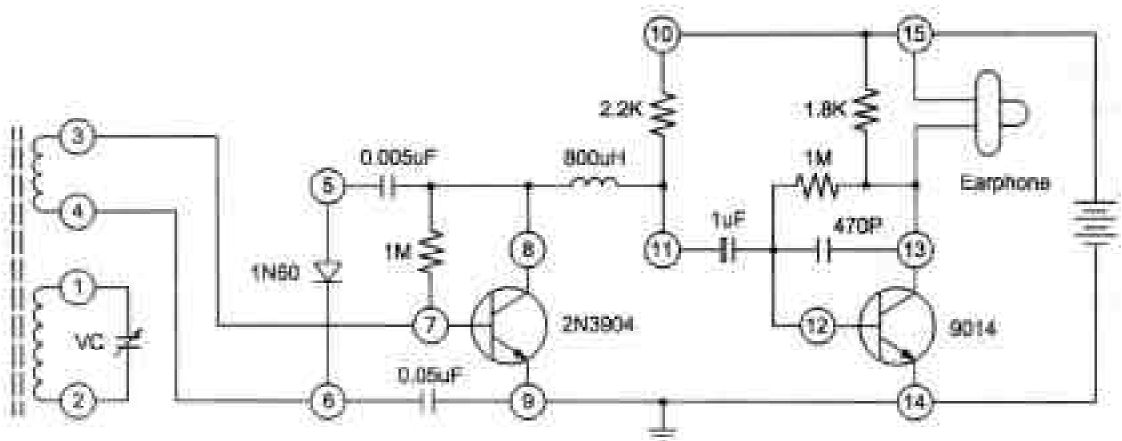
Electronic Radio Model with 2-transistor amplifier

Refer to the following illustrations of complete unit when you are building the kit.



Circuit diagram:

note the 2N3904 npn bi-polar plastic case transistor; and the 9014 transistor used in the final audio amplifier stage.



AM MW RADIO SCHEMATIC DIAGRAM

Oscillation and Waves

(an excerpt from *Fields, Rays, and Atoms*)

by

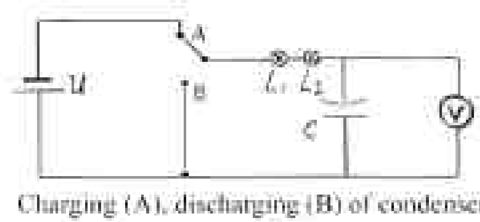
Manfred von Mackensen

The electric and magnetic phenomena which we have investigated thusfar, no matter how they subside, constantly show the tendency that they generally don't escalate on their own: in the realm of visible, macroscopic processes, the voltage between two insulated poles will immediately disappear, and similarly the field created by the current induced from a moving conductor will dampen the motion that produced it (Lentz's law), which in turn limits the original current, if there is no outside source of work to maintain the movement.

With the electric field, we have the fading of a more resting (the tension), and with the magnetic field (associated with a current), in contrast, we have the braking effect of the occurrence (the current). Both types of fields are suppressed by nature but in completely different ways. And in this lies precisely the possibility that the suppression of one field can be used to engender the other—as should now be shown in the lessons. After we have become acquainted with the time delaying produced by a current in a coil (self-induction) in the foregoing section, it is now appropriate to investigate time delay from a capacitor.

Time-delaying with the Capacitor

Charging and discharging processes in a capacitor. A capacitor as large as possible (10,000 uF) is connected in parallel with a voltage measuring multimeter, with a 10–100v power source and also wired in series with one or more lamps (24-30v, 50-100mA; switch position A). The values are chosen so that the voltmeter reaches full scale deflection after about one second, and the lamps fade out as slowly as possible.



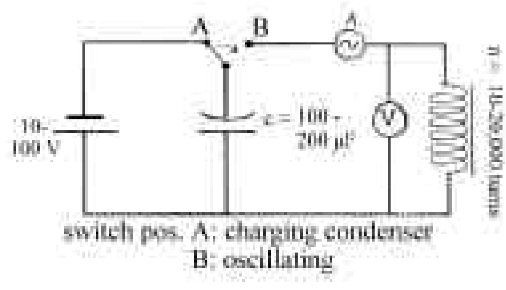
Charging/discharging Capacitor

When we change the switch to position B, the charging process can happen. With charging up the capacitor, initially we see that the current takes on its maximum value earlier than the voltage. (The lamps go out while the voltmeter needle deflection still increases.) This is in contrast to the coil where the current of the (induction) voltage subsides (see above). During charging, the speed of meter deflection is clearly slower towards the end; the charging current is proportional to the residual voltage.

Oscillator L-C Circuit

If a condenser is freshly charged and then switched into a circuit (with an ammeter with very high inductivity), then we can successfully show the so-called electromagnetic oscillation as a fading AC current. With this, we can explore undamped oscillator circuits.

> *Slow, undamped oscillator circuit:* The coil needed for the following circuit, in addition to having a high number of windings, should also have a highly permeable core[1]. For the capacitor we could use several MP-condensers in parallel (for example, from a washing machine, etc.). The multimeter should be a quick response voltmeter with high ohmage, set for a middle null-point; the ammeter low ohm (10 mA range).



Oscillator

On the basis of the oscillation cycle, we can now carefully consider that the current associated with the voltage fluctuations and the voltage with the varying current are both proportional. This can be clarified by means of a diagram which shows the variation of the voltage over time.

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[1] In any case we should not push the applied voltage too high, in order to avoid coming into the saturation range of the iron core, where the hysterysis curve is flatter, i.e., the permeability is smaller.

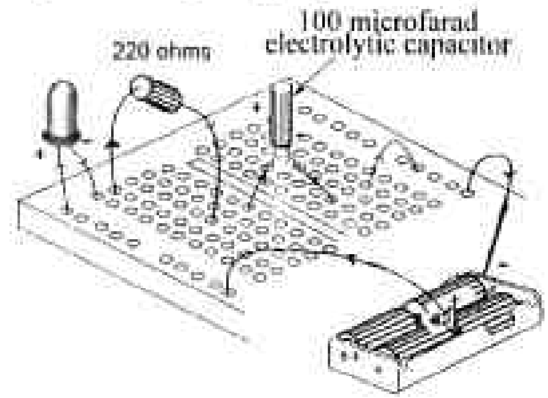
The Capacitor

The Capacitor (or condenser) is a device that stores electric charge when connected to a source of electric power. Capacitors are constructed with two metal plates separated by an insulator (called the dielectric) such as mica, paper, or air. Capacitors allow the passage of alternating current, but block the flow of direct current. Capacitance is usually measured in micro-Farads (uF, or mFd) or pico-Farads (pF), since the Farad is too large a unit. Components with a capacitance of 1uF is 1,000,000th of a Farad.

Some capacitors are electrolytic and others are non-electrolytic. When connecting electrolytic capacitors, correct polarity needs to be observed. The positive (+) lead is usually longer than the negative (-) lead and is usually marked on the body. Ceramic capacitors are non-electrolytic and can be connected either way. The value of a capacitor is painted on the body of the component; for electrolytic capacitors, the value will be given as a number (22uF) and the maximum voltage (16v).

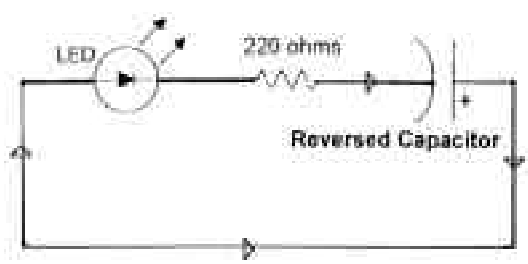
When a large-value capacitor is fully charged, it holds a high voltage capable of discharging extremely high current though its terminals. It is therefore dangerous to touch the leads of an electrolytic capacitor if there is any chance it has been charged; it can hold a substantial charge even after the equipment has been unplugged from the power source.

Capacitor being charged by the battery



EXPERIMENT 13: CAPACITOR IN A CIRCUIT

Wire up the circuit shown (both as a schematic circuit diagram, and as the breadboard layout). Once the circuit is connected to the power source, the LED glows for an instant and then goes out. This indicates that the battery drives the electric current through the resistor and through the LED for an instant, causing it to light up. If the flash is too brief, use a higher value resistor (300W or more) and a bit higher voltage.

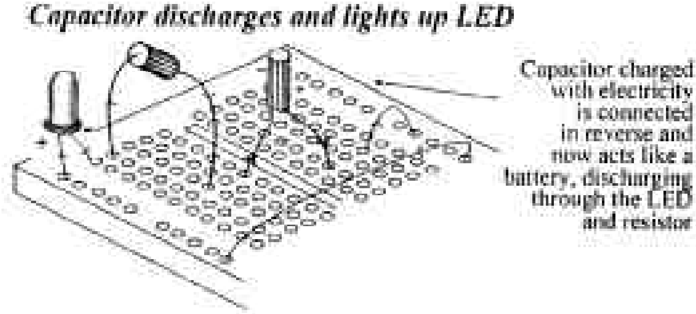


EXPERIMENT 14: CHARGING & DISCHARGING A CAPACITOR

Repeat the process of experiment 13, charging up the capacitor in the circuit above. After you see the LED flash, disconnect the power.Now, gently pull out the capacitor and reverse its leads in the breadboard holes, as shown to the right. Finally, touch the ends of the power leads to each other to complete the circuit (as shown across the bottom of the breadboard). The LED briefly flashes again. This means the energy (stored as a charge in the capacitor) has been able to discharge through the circuit and the LED, causing it to light up.

Notice how the capacitor introduces a time element into circuits: they can "remember" the conditions of an earlier moment, and hold some aspect of that (the charge that was applied to the circuit) into a later time.

Capacitor discharges and lights up LED



This article was inadvertantly left out of the *Proceedings for the Mathematics Colloquium–Research Project #3,* available from AWSNA Publications, and is included in the revised edition. If you have an older version, please photocopy this and place it in your book.

Marty Levin wrote the article at the request of colleagues at Waldorf teacher training centers who were asking the question, “What background preparation at the university is needed for individuals desiring to teach math in a Waldorf high school?”

— DSM

Qualifications for High School Mathematics Teaching

by
Marty Levin

The Need for Expertise

In a Waldorf/Rudolf Steiner high school, each teacher has the responsibility for shaping the curriculum he or she teaches. When the inevitable “Why do we have to do this?” comes from the students, the teacher following someone else’s program is less able to give a convincing answer than the teacher who, out of knowledge and love of their subject, brings what he or she has chosen as significant and interesting. Teachers who lack expertise to meet the above question with authority invite cynicism. Advanced training in mathematics is essential to enable the teacher to shape a suitable curriculum with confidence, which engages the students in meaningful work. This fosters hope and idealism. We must not content ourselves with a mathematics program which is essentially a conventional state school program with a projective geometry block thrown in, taught by people whose main fields of interest are elsewhere.

Students need to have a mathematics teacher who has specialized in the subject and loves it, someone who spends his or her free time doing mathematics, because he or she finds it beautiful and meaningful.

Requirements

A prospective teacher with a background in basic Anthroposophy and Waldorf pedagogy and otherwise suitable for high school teaching should have the following additional qualifications for the teaching of high school mathematics:

1. A bachelor’s degree with a major in mathematics

It should include at least twelve one-semester mathematics courses, two semesters of computer science, and at least two semesters of courses in other areas where mathematics is applied or the equivalent.

Rationale: The teacher needs to know what skills will actually be needed by the high school students in the various university or college courses they may later take. For example, the old traditional full year grade 10 course on Euclid includes a lot that is almost never used later.

Having the perspective of advanced and more abstract mathematical theories makes possible an entirely different quality of teaching. Firstly, one can bring into the high school curriculum advanced ideas which show connections between elementary topics. For example, matrices make much more sense when introduced in connection with linear transformations. Secondly, the more sophisticated theories often answer questions as to what is possible and not possible in a more elementary topic. This helps in formulating exercises and in answering students’ questions. Most importantly, it helps one to see where a student’s new idea might lead. One can help the student (or the whole class) work the idea through to a new solution of a problem or perhaps to an understanding of why the idea doesn’t work. (It’s wonderful to see how the students faces “light up” when that happens!) Thirdly, the teacher can put an elementary topic into context with brief comments about its connection to more advanced questions, thereby making the subject much more interesting. Fourthly, the experience of the elegance and beauty found in many of the advanced theories in mathematics gives the teacher an ideal to strive toward in the crafting of his own lessons on elementary topics.

2. A study of the following topics which may or may not have been included in the bachelor's degree work (Some of these subjects may be available only piecemeal in various courses at any particular university or perhaps not at all.)

• A. History of mathematics.

One university course or the equivalent. It should include biography, bibliography of original source material, the great foundations crises, and "Non-Euclidean Geometry before Euclid," by Imre Toth in *Scientific American*, November 1969.

Rationale: Firstly, historical and biographical material is needed in order to present the mathematics in context. This is especially important in main lessons. Secondly, a study of the history of mathematics in the light of Anthroposophy can lead to understanding of the complementary roles in mathematics of imagination and intuition on the one hand and form and formalism on the other hand. One can then see that present-day mathematics teaching overemphasizes the form and that our task is to find ways to balance this with a conscious development of the imaginative and intuitive side.

• B. Mathematical logic.

At least as far as the proofs of Godel's theorems.

Rationale: Needed for a clear understanding of the role of proof and formalism in mathematics.

• C. Projective geometry

Fundamental theorem, theorems of Desargue, Pascal, and Brianchon, duality, polarity, homogeneous coordinates, cross ratio, conic sections.

Rationale: Rudolf Steiner pointed to projective geometry as a discipline which, when approached imaginatively, can develop a thinking which is both clear and mobile and which is suitable to an understanding of the etheric. It is a preparation for the development of higher cognition.

• D. Foundations of geometry

1. Non-Euclidean geometry—characterizations of the three constant curvature geometries, proof of mutual consistency, models within projective geometry, relation to spherical geometry, relation to physical space.
2. Synthetic axiomatic development of Euclidean geometry (a la Hilbert)—inadequacy of Euclid, order axioms, continuity axioms.
3. Foundations of projective geometry—two and three dimensional axiomatic development synthetically and analytically, relation of Desargue and Pascal theorems to coordinate field and existence of three dimensional extension.
4. Klein's conception of a geometry as invariants of a group action.

Rationale: Firstly, this is needed for a clear understanding of the role of formal systems in mathematics. Secondly, it is needed as background for the teaching of projective geometry. The idea of the infinitely distant always stimulates wonderful arguments in high school classes. The teacher needs to be very clear about what it means for something to be "true" in geometry in order to bring clarity to these discussions.

• E. At least an elementary knowledge of the following which are often included in the high school curriculum: spherical trigonometry/navigation, perspective drawing, descriptive geometry (i.e. engineering drawing), surveying, and symmetry.

• F. Mental arithmetic

Rationale: This allows the teacher to quickly return his attention to his pupils.

3. Study of the work of Anthroposophical mathematicians. The following are perhaps the most essential of what's available in English:

- A. *Physical and Ethereal Spaces* by George Adams is an excellent starting point.
- B. *Projective Geometry* by Olive Whicher shows that geometry can be taught through drawing without proof and also that a subject in mathematics can be developed in an orderly fashion in which the order does not derive from the order of proof.
- C. *Projective Geometry* by Lawrence Edwards (Rudolf Steiner Institute 1975), especially parts 10, 11, 12 for the relation of arithmetic to geometry there given, and parts 25 to 29 for an introduction to path curves.
- D. The work of Lawrence Edwards is found in his book *Vortex of Life* or its earlier version, *Field of Form*. The indications of Steiner and Adams find fruition here. Edwards shows us how to see, through the forms of projective geometry, formative forces at work in nature.

Rationale: These works show that mathematics can be used as a tool for the training of a new kind of thinking, one which offers greater possibility for freedom. They show how the imaginative element can be developed, thereby providing a much needed balance to the overly mechanical and formalistic view of mathematics currently prevalent.

4. Study of *Philosophy of Freedom* by Steiner

Rationale: The adolescent wishes to look to himself or herself for guidance and no longer rely on authority figures. The tumultuous emotions are found to be unreliable, but one senses that thinking can be trusted to give guidance in life. Thinking, however, requires training if it is to become reliable. All of the high school curriculum should help to train the thinking, but mathematics especially so, since the realm of thought is really the substance of the subject. In mathematics one encounters thinking which is largely free of sense impressions and value judgments. So here, too, a teacher encounters students' questions, both spoken and unspoken, about the nature of thinking itself. "Is it true or mere opinion that 2+2 = 4?" "What's the point of a proof? Why not measure it?" "You can prove anything, so why should I believe it?" *The Philosophy of Freedom* gives the tools with which to address these questions. The teacher needs to have wrestled with these questions and have come thereby to understand the value and reliability of thinking. Then the teacher is in a position to address the students' doubts. He can speak with conviction about 2+2 = 4 being a reality, not an opinion nor merely a matter of language, but at the same time invite a lively discussion, because he understands that the discussion is itself an opportunity for the students to experience what thinking can do for them. The development of confidence in thinking gives the student the basis for a healthy direction in life.

Compromises

It might be that a candidate has only some of the background listed in (1) and (2) above and other more qualified candidates are not available, leading one to hope that the candidate will be able to acquire the missing background on the job. One must be realistic about such situations. Some of the most creative and successful mathematics teachers have not studied all that is listed here. We must not, however, with wishful thinking, imagine that any ill-trained person could do a competent job. The key questions should be:

- 1. Have the bulk of the above requirements been met?
- 2. Has the candidate learned significant amounts of mathematics on his or her own and thereby demonstrated the ability to acquire the further expertise needed?
- 3. Does the candidate spend time studying mathematics and working on problems simply because he or she loves the subject?

Summary

Qualifications for High School Mathematics Teaching

A prospective teacher with a background in basic Anthroposophy and Waldorf pedagogy and otherwise suitable for high school teaching should have the following additional qualifications for the teaching of high school mathematics.

1. A bachelor's degree with a major in mathematics.

It should include at least 12 one semester mathematics courses and at least 4 one semester courses in other areas where mathematics is applied or the equivalent.

2. A study of the following topics which may or may not have been included in the bachelor's degree work: (Some of these subjects may be available only piecemeal in various courses at any particular university or, perhaps, not at all.)

- A. History of mathematics. One university course or the equivalent, to include biography, bibliography of original source material, the great foundational crises.
- B. Mathematical logic.
  At least as far as the proofs of Godel's theorems.
- C. Projective geometry
  Fundamental theorem, theorems of Desargue, Pascal, and Brianchon; duality, polarity, homogeneous coordinates, cross ratio, conic sections.
- D. Foundations of geometry
  1. Non-Euclidean geometry—characterizations of the three constant curvature geometries, proof of mutual consistency, models within projective geometry, relation to spherical geometry, relation to physical space.
  2. Synthetic axiomatic development of Euclidean geometry (a la Hilbert)—inadequacy of Euclid, order axioms, continuity axioms.
  3. Foundations of projective geometry—two and three dimensional axiomatic development synthetically and analytically, relation of Desargue and Pascal theorems to coordinate field and existence of three dimensional extension.
  4. Klein's conception of a geometry as invariants of a group action.
- E. At least an elementary knowledge of the following: computer science, spherical trigonometry, navigation, perspective drawing, descriptive geometry, surveying, and symmetry.

3. Study of the work of Anthroposophical mathematicians. The following are perhaps the most essential of what's available in English:

- A. *Physical and Ethereal Spaces* by George Adams
- B. *Projective Geometry* by Olive Whicher shows that geometry can be taught through drawing without proof and also that a subject in mathematics can be developed in an orderly fashion in which the order does not derive from the order of proof
- C. The work by Lawrence Edwards is found in his book, *Vortex of Life*, or its earlier version, *Field of Form*. The indications of Steiner and Adams find fruition here. Edwards shows us how to see, through the forms of projective geometry, formative forces at work in nature.

4. Study of *Philosophy of Freedom* by Rudolf Steiner.

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Waldorf Science Newsletter: edited by David Mitchell & John Petering

This newsletter is published twice each year and is dedicated to developing science teaching in the Waldorf schools. Teachers are invited to pose questions, seek resource material, discuss experiments, write about their classes (successful and not very successful), and investigate phenomena. The editors also translate relevant science articles from Waldorf periodicals from around the world. The following past editions are available from:

AWSNA Publications — e-mail awsna@awsna.org
3911 Bannister Road — fax: 916/ 961-0715
Fair Oaks, CA 95628 — phone: 916/ 961-0927

Available from www.awsna.org on-line at: http://www.awsna.org/books_sciencenews.htm

Volume 1, #1

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Volume 1, #2

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